THE UNIVERSITY OF ALBERTA

THE RELATIONSHIPS AMONG PHYSICAL WORK CAPACITY PHYSICAL FITNESS INDEX AND PERFORMANCE TIME IN SWIMMERS THROUGHOUT A SEASON OF TRAINING

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Relationships Among Physical Work Capacity, Physical Fitness Index and Performance Time in Swimmers Throughout a Season of Training" submitted by James Edward Newman in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this study was to investigate the changes in physical work capacity, physical fitness index, and performance time over a season of training in male and female swimmers. It was also the purpose of the study to examine the correlations between physical work capacity, physical fitness index and performance time on three occasions during the training period. A subsidiary problem consisted of examining the effect of swim training on initial, walking, anticipatory and maximal pulse rates.

Thirty-nine swimmers were tested throughout a training period which lasted from nineteen to twenty-six weeks. Swim training sessions were held daily from five to six days a week.

Within the limits of this study, the following conclusions have been made:

1. There were no significant changes in mean PWC_{170} scores for any of the three groups of swimmers during the training season.

2. There were no significant changes in mean performance time scores for any of the three groups of swimmers during the season of training.

3. There were significant increases in mean physical fitness index scores for both groups of male swimmers during

the training season. There were no significant changes in mean fitness index scores for the female swimmers.

4. With regard to their predictive quality, the correlations between physical work capacity and performance time were low and not significantly greater than zero for the male university swimmers, $r = -.23$. The correlations between these variables were moderate and significantly greater than zero for both the male and female groups of teenage swimmers, $r = -.61$ for the males and $r = -.69$ for the females.

5. With regard to their predictive quality, the correlations between performance time and physical fitness index were low and not significantly greater than zero for the university males, $r = .04$ moderate and significantly greater than zero for the teenage males, $r = .-51$ and high for the teenage females, $r = -.73$.

6. With regard to their predictive quality, the correlations between physical work capacity and physical fitness index were low and not significantly greater than zero for both groups of male swimmers, $r = .36$ for the university males and $r = .37$ for the teenage males. The correlations between these variables were moderate and significantly greater than zero for the female swimmers, $r = .58$.

7. There were no significant changes in mean initial pulse rates for any of the three groups throughout the training season.

8. There were no significant changes in mean walk pulse rates for either of the male groups over the training period. There was however a significant decrease in the mean walk pulse rates of the female swimmers.

9. There were no significant changes in the mean pre-run pulse rates for the university swimmers. There was however a significant decrease in the mean pre-run pulse rates for both male and female teenage swimmers.

10. There were no significant changes in mean maximal pulse rates for any of the swimming groups during the training season.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The term "physical fitness" is nebulous: it all but defies definition. Cumming (30) describes fitness as the ability to do physical work and to recover both quickly and completely from that work. Gallagher and Brouha (43) differentiate between three main aspects of fitness:

1. A medical or static aspect which refers to the soundness of various body organs.

2. A functional or dynamic aspect which is comprised of the ability to do strenuous work.

3. An aspect of specific skills which includes the development of muscle co-ordination and strength.

Gallagher and Brouha (43) explain that dynamic fitness is a prerequisite for any vigorous or specific training for any particular skill. Brouha (22) in discussing the dynamic changes which occur as a result of training states that there are improved cardiovascular functions leading to a better supply of oxygen to the muscles. Although the concept of working capacity has not always been defined in the literature, Bengtsson (15) says that it is comparable to some extent with physical fitness.

Anderson (3), and Cumming (30) list a total of twenty

reasons why it is of consequence to examine problems of work capacity and fitness. Of these, four have particular reference to this study:

1. To select athletes for endurance as well as other events.

2. To evaluate athletes and physical training programs.

3. To fully establish the physiology underlying the athlete's superior fitness.

4. To enable comparison of successful athletes with other populations.

Since 1947, studies have been undertaken to examine the reduced capacity for physical work, in men working at an ore smelting works (80), in patients with vasoregulatory asthenia (55), and in patients with funnel chest (17). In more recent years, research has been carried out to determine and compare the physical work capacity of school aged youth in Scandinavia (1,15), California (2), and in Canada (24,32,33). Frick _et_ _al_. (41), and Holmgren _et_ _al_. (56) demonstrated that a program of training increased the work capacity of non-athletic subjects of sedentary habits. Bevegard (18) showed that the work capacity of athletes was the same whether it was determined in the supine or sitting position. Very little is known however, about the physical work capacity of athletes, the effects of training on their

physical work capacity, and the relationship between work capacity and performance in athletes.

The Problem

The purpose of this study was to investigate the changes in physical work capacity, fitness index and performance time over a season of training in male and female swimmers. It is also the purpose of the study to examine the correlations between physical work capacity, fitness index and performance time at three different times throughout the training period.

Subsidiary problem. To examine the effect of swim training on the initial pre-exercise, walking, anticipatory, and maximal pulse rates.

Justification

Cumming (30) states that considering the broad applications of the knowledge of physical fitness, the general knowledge of the health professions relating to fitness is meagre. He further mentions that it has never been proved that a high level of aerobic capacity (cardiovascular fitness) is associated with a general proficiency in sporting events other than endurance running.

Michael and Gallon (70) denounce the fact that most of the studies concerning athletic training compare athletes

with non-athletes or compare before and after conditioning periods. There is a need to show if work capacity changes with training, and if so, how it changes in relation to performance.

In addition, there is a lack of information in the literature with regard to extended training periods. This study involved training programs of from five to six months duration.

Montoye (71) reminds us that not infrequently, achievement and performance in sport are thought to demand a high level of cardiovascular fitness. Because of this, it is not surprising that physical educators and athletic coaches have been intimately concerned with the development of these physiological systems. The determination of the relationships between work capacity and performance during a training season should be useful to coaches and physical education teachers.

In this study, two types of test were used. The Sjostrand Work Capacity Test determines the work capacity of an individual at a heart rate of 170 beats per minute. The subject's heart rate is the criterion used for establishing work loads. As a result, motivation has little or no effect on the final test score.

The Modified Johnson Brouha Darling Physical Fitness Test determines an individual's fitness index. This index

is dependent on the length of time a subject can run on a treadmill, and on the degree of heart rate recovery after the exercise. Motivation greatly influences the length of time run and therefore affects the final test score.

Use of the Sjostrand Work Capacity Test. The advantages for using this test are:

1. It is an internationally accepted test of work capacity (24).

2. The apparatus involved while neither costly or bulky is easily moveable. This makes it a practical apparatus for field work (15,24,93).

3. The testing period is short (93).

4. It requires only submaximal energy expenditure and is therefore less demanding on the subjects than a maximal test (24).

5. It has a high relationship with maximal oxygen intake tests (24,93).

6. The simple testing procedure facilitates the training of testing teams (2,24).

7. It meets the generally accepted criteria for tests measuring cardiovascular function: a) a large muscle mass is involved; b) various parameters are easily measured during the test (24,93).

8. It is both objective and reproducible (2).

9. The results readily permit comparison of various groups (2).

Use of the Modified Johnson Brouha Darling Test of Physical Fitness. The advantages of this test are:

1. It is performed on a motor driven treadmill and also meets the generally accepted criteria for tests measuring cardiovascular function: a) a minimum amount of skill is involved; b) work load is adjusted automatically to body size (14).

2. By allowing the subjects to run to exhaustion, it serves as a maximal test.

3. It is useful in following quantitatively the improvement of the same subjects with physical training (60).

4. It assesses the relative fitness of different individuals for hard work (60).

5. It is a performance test and aids in detection of individuals who are unwilling to exert themselves. In many performances, perserverence and will power are equally as important as actual physical ability. Athletes who are not willing to work diligently are unable to achieve a state of superior training (60).

Delimitations

1. This investigation was limited to thirty-nine active swimmers who trained in the City of Edmonton area.

2. Physical work capacity and physical fitness index, two of the variables studied, were dependent upon heart rate,

3. The training program lasted from five to six months.

Limitations

1. The temperature and humidity in the testing laboratory were not rigidly controlled.

2. The eating and sleeping habits of the subjects were not controlled at any period of the study.

3. The Modified Johnson Brouha Darling Physical Fitness Test is a performance test and thus involves motivation. Because of this, the co-operation of the subject is required. If the subject stopped before he was tired, his fitness score would underestimate his physical abilities.

Definitions

Anticipatory (pre-run) Heart Rate*. The heart rate measured thirty seconds before the maximal run on the Modified Johnson Brouha Darling Physical Fitness Test.

Initial (pre-exercise) Heart Rate. The subject's heart rate measured, after entering the laboratory, following a five minute rest in the seated position.

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*All heart rates were calculated from E.C.G. recordings as described in Chapter III

Kilopond Meter (KPM). A unit of work performed by a force moving a mass of one kilogram through a distance of one meter at the normal acceleration of gravity.

Maximal Heart Rate. The heart rate measured after an all out treadmill run, on the Modified Johnson Brouha Darling Physical Fitness Test.

Performance Time. For Group I, the time in seconds required to swim 100 yards in a twenty-five yard pool. For Groups II and III, the time in seconds required to swim 100 meters in a twenty-five meter pool.

Physical Fitness. The ability to perform prolonged heavy work involving the action of large muscle groups contracting with submaximal force for relatively long periods of time (79).

Physical Fitness Index. The ratio of maximum time run on a treadmill, to the sum of three thirty second recovery pulse rates.

$$\frac{100 \text{ X duration of the run in seconds}}{\begin{array}{l}\text{2 X (sum of three 30 second pulse rates taken} \\ \text{between } 1\text{-}1\tfrac{1}{2}\text{; } 2\text{-}2\tfrac{1}{2}\text{; } 4\text{-}4\tfrac{1}{2} \text{ minutes of recovery)}\end{array}}$$

Physical Work Capacity (PWC_{170}). The work intensity in KPM per minute which the subject could perform at a pulse rate of 170 beats per minute (18).

Time Run. The time run in seconds by subjects on the Johnson Brouha Darling Physical Fitness Test.

Walking Heart Rate. The heart rate measured after walking $4\frac{1}{2}$ minutes on the Modified Johnson Brouha Darling Physical Fitness Test.

Work Load. The calibrated frictional force applied to a friction belt which the subject must overcome to continue cycling at a rate of sixty revolutions per minute (93).

In this investigation, physical work capacity and physical fitness index are two concepts used to describe the dynamic, functional, cardiovascular aspect of fitness.

CHAPTER II

REVIEW OF THE LITERATURE

I. ASSESSMENT OF PHYSICAL WORK CAPACITY AND PHYSICAL FITNESS

Astrand (9) states that the quantitative assessment of physical fitness is one of the most complex and controversial problems in applied physiology. This predicament originates in part from a lack of general agreement on what constitutes fitness for withstanding different sorts of work, and in part from lack of accordance on what measurements allow valid comparisons to be made among different individuals.

Methods of Assessing Fitness

Henry and Berg (52) explain that since fitness is a concept, it is difficult to tangibly evaluate. Because of this, there is as yet no single test which has enjoyed general acceptance as an appropriate measure of physical fitness (43,53).

Schneider (78) differentiates between two categories of fitness tests:

1. Performance tests, which measure the amount and character of work completed.

2. Non performance tests, which measure physiological

responses to a given activity.

Some investigators support the use of performance tests while others prefer the measurement of physiological responses. Taylor et al. (83) compared the responses of a group of subjects to submaximal and maximal work in repeated experiments. Time run in the maximal test was more reliable than any of the physiological parameters in measuring exercise tolerance. Cooper (27) correlated test scores on a twelve minute performance run with maximal oxygen consumption and found the correlation to be r = .897. Contrary to the findings of Cooper, however, Hodgson et al. (54) computed zero order correlation coefficients between performance measures and physiological measures associated with maximal and submaximal work. The performance measures consisted of the times for fifty and two hundred yard runs, as well as the time required to produce exhaustion on an all out step test.

Henry and Berg (52) on the other hand assert that performance tests tend to become quite specific, with the result that they are poorly adapted to the estimation of general work capacity. Henry and Berg are consequently of the opinion that physiological measures are more effective than performance measures, in demonstrating improved physical fitness resulting from a training regime.

Over the years, many physiological measures have been

obtained for the purpose of assessing fitness. These include:

1. The determination of vital capacity (78).

2. The assessment of breath holding ability (78).

3. The determination of cardiac output (9).

4. The recording of change in pulse rate on going from a sitting to a standing position (78).

5. The evaluation of recovery heart rate after exercise (60).

6. The recording of change in blood pressure on shifting from a sitting to a standing position (78).

7. The assessment of total body hemoglobin (9).

8. The systematic semiquantitative determination of protein in the urine (42).

There is general agreement that no one measurement provides an accurate assessment of cardiovascular fitness (34). Many physiologists (9,11,13,27,30,33,72,84,85) are of the opinion however, that maximal oxygen intake is the best single indicator of the capacity for sustained hard work in man.

<u>Relationship Between Heart Rate and Maximal Oxygen Intake</u>

Due to the need for expensive equipment, and elaborate laboratory techniques, the determination of maximal oxygen intake is often impractical.

A rectilinear relationship has been demonstrated between heart rate and oxygen consumption (6,9,10,87,92). Wyndman *et al*. (92) found that the curve of heart rate and maximal oxygen consumption was linear up to a point near the maximum value of heart rate. This relationship has been the basis for the development of several submaximal work capacity tests, including the Sjostrand PWC_{170} Test.

As a rectilinear relationship has also been shown between heart rate and work load (9,66,77,87), Sjostrand (80) and Wahlund (87) consider that pulse determination is a suitable indicator of working capacity in adults. Cumming and Danzinger (33) studied both PWC_{170} and maximal oxygen consumption in Canadian children. From this investigation they concluded that heart rate is a valid criterion for the assessment of physical work capacity in children as well.

II. TESTS OF PHYSICAL WORK CAPACITY AND PHYSICAL FITNESS INDEX

Sjostrand PWC_{170} Test

Underlying theory. The Sjostrand Test is based on the rectilinear relationships between heart rate and maximal oxygen consumption, and between steady state pulse frequencies and the work loads producing these pulse frequencies (24). At a heart rate of 170 beats per minute, the adults

studied by Wahlund (87) were working at eighty per cent of their aerobic capacity. Cumming and Danzinger (33) found that ten and eleven year old children were working at seventy-three per cent of their maximal oxygen consumption at a heart rate of 170 beats per minute.

Validity. Wahlund (87) determined that as long as the subject had not reached the point of exhaustion, oxygen consumption could be predicted from work load. In two-thirds of the cases studied this estimation was accurate within a range of $\pm$ 8 per cent.

De Vries and Klafs (cited in 93) investigated the correlation of the Sjostrand Test to a modified Mitchell, Sproule and Chapman Test. They found that maximal oxygen intake correlated with the Sjostrand Test ($r = .703$, significant at the .01 level). Oxygen intake/kg correlated to the Sjostrand Test expressed in kpm/min ($r = .573$, significant at the .05 level). Oxygen intake/kg was correlated to kpm/min/M^2 ($r = .762$, $p = .01$) and to kpm/min/kg ($r = .877$, $p = .01$). Mendryk (67) suggests that such results can most easily be interpreted by use of the relationship $(r^2 \times 100) + (k^2 \times 100) = 100$. In this formula, r^2, the coefficient of determination, represents the percentage of variance of one variable which is predictable from the variance of the other variable. The coefficient of non-determination k^2 then represents the percentage of unexplained variance. For the

above correlations r^2 x 100 is equal to forty-nine per cent, thirty-three per cent, fifty-eight per cent, and seventy-seven per cent respectively.

Reliability. In a study involving thirty-eight male high school students, Zahar (93) demonstrated that the Sjostrand Test is a highly reliable measure of physical work capacity. Each subject took the PWC_{170} Test six times. Correlations between trials ranged from r = .809 to r = .947. All correlations were significant at the .01 level.

Watts (90) determined the test-retest reliability of the PWC measure on nine male university students. The correlation of reliability was found to be r = .89.

Evolution of the test. Sjostrand (80) used a form of the test to investigate changes in respiratory organs of workmen at an ore smelting works. The test consisted of pedaling at two ten minute work loads, and one four to six minute work load. The work continued until the heart rate exceeded 175 beats per minute, or until the increase between two recorded heart rates at a given work load was more than ten beats per minute.

Wahlund (87) reduced the duration of each work load to 6½ minutes. Work loads were increased by increments of 300 kpm per minute. When the subject could no longer pedal, or when he had reached a work load of 1200 kpm per minute,

the test terminated. The maximum heart rate at which work could be performed satisfactorily was set at 170 beats per minute. If this heart rate was not reached, the work that would have been done at this heart rate was estimated from the known relationship between heart rate and work load. The value was designated as Physical Work Capacity 170 (PWC_{170}).

The next modification consisted of reducing each work load to a duration of six minutes. Bengtsson (15) standardized the pedalling rate to a range of forty-five to sixty revolutions per minute. He also endeavored to regulate the resistance in such a way that the heart rate would be between 115 to 130 beats per minute at the first work load, between 140 to 150 at the second, and approximately 170 beats per minute at the third.

This is the basis of the test used in this study. There are however several other variations of this test that are commonly used. Adams _et al_. (1) reduced the number of workloads from three to two. An attempt was made in that test to elicit a heart rate of 140 beats per minute during the first work load and a heart rate of 170 during the second. In the recently completed C.A.H.P.E.R. study (24), a twelve minute test replaced the previously used eighteen minute version. In the twelve minute test every subject pedalled at three workloads, each of four minutes duration.

Modified Johnson Brouha Darling Test

Underlying theory. This test is based on two hypotheses:

1. That a fit individual can run longer on a treadmill than one who is not fit.

2. That there will be a faster rate of recovery, as measured by heart rate, in a fit subject after exercise.

While the first principle appears to be generally acceptable, there is a certain degree of controversy with regard to the second. Sedgwick (79) studied forty subjects aged seventeen to thirty-five. He found no significant relationship between recovery heart rate and time run on the Johnson Brouha Darling Fitness Test. It was however demonstrated that subjects with higher maximal oxygen intakes were able to run longer. The correlation between MVO_2 and Johnson Brouha Darling Index equals .66 ($r^2 \times 100 = 43$ per cent). Bengtsson (15) investigated the work capacity of normal children and discovered that recovery pulse rates taken at four and ten minute intervals after exercise were only of little value in estimating work capacity.

Other investigators (4,9,19,22,60,70,74) however, indicate that recovery pulse rates are a valid criteria of the physical state of subjects. Carlile (25:118) found a high correlation between swim time and the sum of three ten

second pulse counts, one started within five seconds of finishing the swim, the second started thirty seconds after finishing, and the third one minute after finishing. Brouha (22) enumerates some of the physiological changes which occur as the result of training. These changes include quicker heart rate recovery after exercise. Robinson *et al*. (74) observed various physiological factors in trained and untrained men, at rest and at four grades of work. The average recovery heart rates were much quicker in runners than in non-athletic young men. At the hardest work load, the recovery heart rates of athletes as well as non-athletes declined at the same speed, during the first half minute of recovery. For the next five minutes of recovery however, the runners' pulse rates fell more rapidly. Andersen (4) also compared athletes with non-athletes and indicated that the recovery heart rate value in a champion athlete is lower than that of a sedentary man. He also reported that heart rate recovery times in women are significantly longer than those in men.

Astrand (9) and Durnin *et al*. (36) help to clarify the merit of using recovery heart rates by explaining that recovery heart rate values can be used to follow one and the same individual during a training period but not in the comparison of physical fitness between different individuals.

Validity. Glassford _et al_. (45) and Sedgwick (79) compared the Johnson Brouha Darling Fitness Index to three tests of maximal oxygen consumption. When comparing maximal oxygen consumption in liters/min to fitness index, the correlations ranged from r = .68 to r = .83. When comparing ml/kg/min to fitness index, the correlations ranged from r = .63 to r = .65. In terms of explained variance ($r^2 \times 100$) these values range from forty to sixty-nine per cent.

Reliability. Watts (90) administered the Modified Johnson Brouha Darling Physical Fitness Test to nine male university students on two consecutive days. The correlation of reliability was determined to be r = .92.

Background of the test. Johnson _et al_. (60) described a rapid simple test of fitness for strenuous exertion that had proved useful in picking out the best, the worst, and the average in groups of healthy men. It also proved helpful in following variations in the physical condition of a given subject, examined at intervals. This original test required that the subject either run to exhaustion, or run for a maximum of five minutes, whichever occurred first.

III. TRAINING

Effect of Training on Performance

Training consists of repeated periods of exercise (22)

resulting in a more economical and precise execution of the recurring maneuvers (49). Knehr *et al*. (65) observe that exercise repeatedly carried out leads to an improved performance. Hemingway (49) distinguishes between two distinct kinds of training:

1. The disciplining of the individual in patterns of movement, which are already within his capabilities, so that a certain result will be produced.

2. The development of the resources of the individual so that they become enlarged and he is able to undertake tasks which originally were beyond his capabilities.

In order to show the relationship between physical fitness and sports performance, Cureton (34) administered the Harvard Step Test to Emil Zatopec and Roger Bannister, two world class track athletes. They obtained similar scores and were the two best Cureton had ever observed on this test. Through training, Zatopec and Bannister had excelled in both track performance and fitness score. From this, Cureton concluded that there was a high relationship between physical fitness and sports performance.

Robinson (73) and Robinson and Harmon (75) trained nine non-athletic college men for a period of twenty-eight weeks on a program of middle distance running. At the end of the training program there was consistent improvement in the four distances tested: the half mile; three-quarter mile; one mile

and one mile and a half. There was also a concurrent increase in the performance of an all out treadmill run.

A variety of training programs are reported to have improved different performance scores in non-athletes. Knehr et al. (65) trained fourteen subjects at two grades of work on a motor driven treadmill. After six months of training there was a mean increase of sixty per cent in the amount of work the subjects were able to perform. After an eight week training program that consisted of calisthenics, cross country running and playing handball, Cureton and Philips (35) observed increased performances in the mile run, five minute step test and all out treadmill run. Ikai et al. (58) found that a month of daily training on a treadmill prolonged all out running time. Cooper (27) examined 115 U.S. Air Force personnel on a twelve minute field performance test. After training, the subjects could run farther in the twelve minute test period and thus obtained improved test scores. Karvonen and Barry (63) report the affects of a six month program of progressive endurance exercise and running on fifteen sedentary middle aged men. After the six month period, the subjects were able to pedal for longer periods against increasing resistance. Their all out run time on the treadmill was doubled. All could complete the Harvard Step Test, whereas at the beginning, some could not. The time for the mile run decreased from 8:51 to 7:36 minutes.

Hammer (47) investigated varsity football players during a season of training. There was an improvement of agility as measured by a sixty yard agility run. Mean scores decreased from 16.4 to 16.0 seconds over the training period.

Brouha (22) concludes that with training, any normal individual can improve his working capacity. Outstanding athletic performances, however can be achieved only by a comparatively small number of athletes whose physiological mechanisms are highly efficient and precisely integrated. The champion athlete possesses innate capabilities both mental and physical. These are developed through training and lead to outstanding athletic performances.

Performance and sex. Although men are superior on most performance measures, the potentiality to better a given performance by training appears to be about the same for both sexes, taking into account that females start at a lower initial level and reach a lower maximum (22).

Effect of Training on Work Capacity

Holmgren *et al*. (55) noted a continuous highly significant improvement in PWC_{170} after a six week program of systematic physical training in eight patients suffering from vasoregulatory asthenia.

Holmgren *et al*. (56) examined eighty-seven normal,

sedentary hospital personnel before and after a training program. One group undertook a program of intermittent training, while a second took part in a regime of continuous training. On being retested, both groups showed a significant increase in PWC_{170}.

After two months of hard basic military training, Frick *et al*. (41) found that fourteen sedentary males had an increase of twelve per cent in their PWC_{170} values.

Tuttle (86) measured work capacity in 172 females. The subjects were divided into three groups. The group consisting of physical education majors who participated in regular bouts of strenuous exercise had a significantly greater capacity to do work than either student nurses or a randomly picked group of subjects.

Wahlund (87) studied twenty-seven athletes. The group consisted of four cyclists, four swimmers and a combination of middle, long distance and ski runners. He concluded that there was apparently no marked difference, in ability to perform work on a bicycle ergometer, between the subjects engaged in different types of athletics.

Physical work capacity and age. In studying a cross section of Canadian children, it was found (24) that there was a continuous increase in mean PWC_{170} for each group from seven to seventeen in the male sample. On the other hand,

this increase ceases in females at age thirteen, at which time a levelling occurs. It is generally agreed in the literature that physical work capacity increases steadily with age up to a peak, after which, it levels off and gradually declines (1,2,10,15,32).

Physical work capacity and sex differences. In the study of Canadian children (24), males were reported superior to females with regard to PWC_{170}, throughout the entire age range of seven to seventeen. Astrand (10) and Bengtsson (15) remarked that there were no significant differences in work capacity up to age fifteen between males and females. After this age however, males had values thirty per cent higher than those of females. There is general agreement that PWC_{170} values for males are greater than those for females (1,2,32).

Physical work capacity and weight. In the study of Canadian youth (24), the correlations between body weight and PWC_{170} were calculated for each age group separately. For males, correlation coefficients ranged from $r = .23$ to $r = .60$. For females, correlations ranged from $r = .21$ to $r = .51$. When these correlations were calculated by combining the scores of all subjects regardless of age, the correlation coefficient for the boys was $r = .80$ and for the girls $r = .60$. The procedure of combining scores of groups of subjects of a heterogenous age range often causes a

spurious correlation which generally tends to overestimate the true relationship.

Cumming and Cumming (32) determined a correlation between PWC_{170} and body weight of r = .897 for boys and r = .696 for Winnipeg girls.

Adams _et al_. (1,2) also found that physical work capacity increases with increased weight.

Physical work capacity and height. Cumming and Cumming (32) calculated correlations between PWC_{170} and body height for Winnipeg children. These values were: r = .865 for boys; r = .658 for girls. Adams _et al_. (1,2) generally consider work capacity to increase with increased height.

Effect of Training on Physical Fitness Index

There generally appears to be an improvement of fitness scores with training. Johnson, Brouha and Darling (60) administered their fitness test to three subjects before and after a training period. There was an increase of mean fitness score from 52.7 to 92.3 units.

Johnson and Brouha (59) compared a group of forty subjects that consisted of athletes and non-athletes. Of this group, the oarsmen who were in active training had better fitness indexes than the other subjects not in training.

Michael and Gallon (70) subjected a team of seventeen

varsity basketball players to a one minute step test before, during and after a season of training. After the first six weeks of training there was a significant increase in fitness indexes. When training was continued for an additional ten week period, no significant changes occurred. After the first six weeks of practice, the fitness scores levelled off and were maintained until the seventeenth week of practice at which time the training stopped. With ten to twenty weeks of detraining, fitness scores deteriorated, thus confirming the training changes.

Sloan and Keen (81) report the effects of physical training on a group of 100 young males. The subjects included thirty-five oarsmen, forty-five rugby players and twenty medical students who served as controls. The club members trained from two to four months. With training, the fitness index as shown by the Harvard Step Test rose significantly in the two athletic groups. There was no significant difference in physical fitness between oarsmen and rugby players either at the beginning or end of the investigation. Both athletic groups, however, had consistently higher mean fitness indexes than the control group.

After training periods which lasted from ten days to six months, Berg (16), Blohmke (19) and Durnin et al. (36) observed improvements in various measures of physical fitness.

Effect of De-training on Fitness

Knehr et al. (65) assert that any training regime systematically followed will have its most marked results after the first few weeks. Following the initial rapid gains, hard diligent work is necessary if continued progress is to be attained.

Cureton et al. (35) and Brouha (22) agree that fitness once induced is rapidly lost. Brouha states that with intensive training, a lay off of from four to six days is accompanied by a deterioration of fitness. But with a moderate level of training, a stoppage of from seven to ten days is possible without decline in fitness.

Specificity of Training

Brouha (22) comments that physical training increases the efficiency to perform any kind of muscular activity provided the work load is moderate. For heavy work, an individual trained for a specific activity is more efficient and capable of doing more work of that particular nature than of any other kind.

Gallagher and Brouha (43) found that that physical efficiency as determined by a bicycle ergometer and treadmill test was always highest after training in men who were involved in strenuous prolonged activities such as rowing or cross country running.

Hanne (48) observed the influences of sport on basketball players and cyclists. He explains that the differences in the two groups are the result of the specific effect of training schedules and the development of different qualities in each group. With basketball training, the stress was short and intensive. Periods of work were alternated with periods of rest. As a result there was a tendency to develop general fitness, speed and agility. On the other hand, road racing requires that cyclists endure long work under sustained load. This type of training tends principally to develop the capacity for endurance.

Effect of Training on Resting Pulse Rates

The significance of resting pulse to physical fitness is controversial. Gallagher and Brouha (43) maintain that there is no satisfactory correlation between initial heart rates and fitness scores. Cogswell *et al*. (26) observed no change in resting pulse rate during the course of a training program. Henry (51) states that resting pulse rate is not a valid test of performance although it does have validity as an indirect measure of athletic training.

On the other hand, in a wide variety of differing programs, it has been shown that resting pulse rate decreased as a result of training (25,29,38,55,56,69,70,81,82,87). Frick *et al*. (41) and Knehr *et al*. (65) report decreases with

training from five to seven beats per minute. In studying track athletes, Schneider (78) discovered that the frequency of their pulse rates decrease as the length of the run in their main training event increases. Sprinters had the highest pulse rates and marathon runners the lowest.

In general, Schneider (78) asserts that a man in training has a pulse rate of six to eight beats slower than a man out of condition. As a result, athletes and physical education students tend to have lower resting pulse rates than non-athletes (38,50,64).

Karvonen and Barry (63) note however that in subjects with inherited bradycardia, training does not result in a further decrease in heart rate. The bradycardia of training is thought to be caused in part by increased vagal tone (46).

<u>Effect of Training on Exercise Pulse Rate</u>

Training appears to cause a decrease in exercise heart rate. When the heart rate was monitored during submaximal exercise, before and after a training program, it was found that lower values were recorded on completion of the training (5,36,47,82). The effect of training was similar in both athletes and non-athletes, although the athletes showed a greater degree of improvement (5). For any given task, the pulse rate during the work period is slower in the athlete than in the untrained man (78).

If the training period is followed by a detraining period, the pulse rate following a bout of exercise will increase again until it reaches the pulse rate values registered before systematic training was initiated (47).

Effect of Training on Anticipatory Heart Rates

Astrand et al. (8) note that apprehension may have a marked influence on heart rate at rest. Faulkner (39) recorded anticipatory increases in heart rate ranging from 20 to 100 per cent of the resting level. Brouha and Heath (23) noticed that after a warm up walk on a treadmill pulse rates rise, during a rest period preceding an all out run, due to the effects of emotion.

But, during working conditions, emotion has little effect on heart rate. Psychic influence is more or less abolished except under extraordinary circumstances (8).

Faulkner (38) discovered that the anticipatory heart rates of young men are decreased through a series of five conditioning trials of standardized work intensity. In addition, non-athletes had higher anticipatory heart rates than athletes both initially and terminally.

Effect of Training on Maximal Pulse Rate

Maximum heart rates after exercise ranging from 167 to 217 beats per minute have been recorded (10,21,32). Cureton (34), Gallagher and Brouha (43) have observed a drop

in the maximum heart rate during exercise as the result of athletic training. Brouha and Heath (23) noticed that for a run of the same duration the maximum pulse of trained subjects is usually lower than that of untrained subjects.

Karvonen (62) observed that if the pulse rate during running was increased less than sixty per cent of the range available from resting rate to maximum obtainable, no training effect on heart rate during running was observed.

Effect of Training on Swimmers

Swimmers characteristically possess the low resting heart rate of well conditioned athletes (39). Resting heart rate values ranging from forty-seven to sixty-five beats per minute have been recorded (78,89). Bloomfield and Sigerseth (20) investigated the physiological characteristics of forty-eight university swimmers. Middle distance swimmers had slower heart rates (fifty-two beats per minute) than sprinters (fifty-six beats per minute). At the other end of the scale, swimmers, after maximal exercise, have heart rates which range from 170 to 197 beats per minute (39,89).

Various techniques have been suggested to obtain optimal training effect on heart rate. Earey (37) recommends that the most effective response is achieved when the heart rate at the end of a single repetition is between 150 to 180 beats per minute in interval training. He maintains

that endurance is best developed in interval training when exercise periods cause the heart rate to increase to two or three times its resting rate, and in the recovery periods to drop to a value fifty per cent above the normal resting rate, before repeating the exercise. Michael (68) trained twelve swimmers for underwater swimming. A combination of breath holding and muscular activity (underwater swimming) resulted in a significant decrease in recovery heart rates and increase in step test scores. At no time during the training did the heart rate rise above 135 beats per minute. This appears to contradict Karvonen's theory that the exercise must elevate the heart rate above 135 beats per minute before a training effect will occur. Counsilman (29) is of the opinion that no single training method is capable of developing speed, muscular endurance, and cardiovascular endurance. All three are qualities essential to a successful swimmer. The exact proportions of each needed in an athlete depend primarily upon the time of the season and the distance for which he is training. To obtain the most desireable results, Counsilman advocates a system of integrated training with heart rates ranging from 97 to 180 beats per minute during each workout. This system of integrated training consists of a combination of interval, over-distance, fartlek, repetition, and sprint training methods.

There appears no doubt that swim training severely

loads the body's oxygen transporting system (12). Cureton (34) states that swimming for speed is shown to be mainly power and skill for sixty to seventy-five feet, but as distance lengthens the circulatory respiratory fitness looms as the dominating factor

Howell et al. (57) administered the Balke-Ware Treadmill Test to ten university swimmers before, during, and after a season of training. Before the season, the group had a mean performance time of 18:15 minutes. On two tests during the season, mean performance times increased to 20:50 and 21:01 minutes. On a final test one month after the training season, mean performance time decreased to 19:30 minutes. These changes were significant at the .001 level of confidence. In addition, there was a significant lowering of exercise heart rates taken at the fifteenth minute of the test, as the training progressed.

IV. SUMMARY

The assessment of physical fitness is one of the most complex and controversial problems in applied physiology. While both performance and non performance tests have been used to evaluate fitness, many physiologists are of the opinion that the measurement of maximal oxygen intake is the best single indicator of the capacity for sustained hard work in man.

Because the determination of maximal oxygen consumption is often impractical, submaximal tests such as the PWC_{170} test, based on the rectilinear relationship between heart rate and oxygen consumption, have been developed. Scores from both the Sjostrand PWC_{170} Test and the Modified Johnson Brouha Darling Physical Fitness Test have been shown to have relatively high correlations with tests of maximal oxygen consumption. It has also been demonstrated that both tests have a relatively high correlation of reliability when subjected to a test re-test evaluation.

Training is considered to consist of repeated periods of exercise resulting in a more economical and precise execution of the recurring maneuvers. Different experimenters have demonstrated that training improves various kinds of performance measures. In addition training has also been shown to increase PWC_{170} and fitness index scores.

While the significance of resting pulse rate to physical fitness is controversial, in a wide variety of differing programs, it has been found that resting pulse rate decreased as a result of training. Training has also been reported to cause a decrease in exercise, anticipatory, and maximal pulse rates.

Swim training is considered to develop speed, muscular endurance, and cardiovascular endurance. Besides improving swim times, it has been shown that swim training increases performance time on the Balke-Ware treadmill test.

CHAPTER III

METHODS AND PROCEDURE

Subjects

The subjects consisted of thirty-nine active swimmers. Group I consisted of nine males, ages sixteen to twenty-two, from the University of Alberta varsity swimming team. Group II was composed of sixteen males, ages thirteen to eighteen, from the South Side and Y.M.C.A. Swim Clubs of Edmonton. Group III included fourteen females, ages thirteen to seventeen, from the same two swim clubs.

Experimental Design

Each subject was given a test battery three times during his training season. The test battery was comprised of, the Sjostrand Physical Work Capacity Test, the Modified Johnson Brouha Darling Physical Fitness Test, and a performance test which consisted of recording each athlete's swim time. For Group I, the times for the 100 yard freestyle event were registered, for Groups II and III, 100 meter freestyle times were recorded.

Groups II and III were tested on three week-ends, once at the beginning, once at the middle, and once at the end of their training season. One test was taken on Saturday and the remaining test on Sunday of each week-end. The testing order was randomly assigned. An attempt was made to

keep the following constant during the three testing sessions; the time of day the test was taken and the order in which each subject was tested. Due to problems of transportation and scheduling, this was not always possible. The first testing session was held on a week-end in early November, the second on a week-end in late January, and the third on a week-end in mid May. The testing was therefore conducted throughout a training period of twenty-six weeks duration.

Due to the busy schedules of the university students, Group I was tested during the school day whenever a mutually convenient time could be arranged. The first set of testing was completed at the end of October, the second set at the end of January, and the third set in mid March. This last test battery was administered from one to two weeks after the final meet of the season. The testing was carried out during a nineteen week training period.

Within one to two weeks of the work capacity tests, for Group II and Group III, swim times in an actual meet were recorded. Five subjects from Group II were, for various reasons, unable to compete in the mid season meet. As a result, their best club times for this period were recorded.

As Group I had no meets corresponding to the testing times, time trials were recorded at a competitive practice session.

Training Program

All swimmers practiced regularly with their respective teams. Training sessions were held daily, from five to six days a week.

Standardization of Procedure

Anthropometric data. At each testing session the following data was obtained from each subject: age; height; and weight.

Testers. There were in all six testers, all of whom were familiar with test procedures and techniques.

Laboratory conditions. The first bout of tests were conducted in the laboratories of the Fitness Research Unit at the University of Alberta. All other work capacity and fitness tests were administered in the Faculty of Physical Education Research Laboratory at the same university. It was not possible to control ambient temperature or pressure. The temperature, however, was recorded throughout and was found to be 72 $\pm$ 4 degrees F.

Heart rate recordings. Heart rate was recorded on a Sanborn Viso-Cardiette Electrocardiograph. Models 51, 100 and 500 were used. The leads of the electrocardiograph were connected to three electrodes strapped to the subject's

thorax. The two chest electrodes were positioned at the first intercostal space below each nipple and the pectoralis major muscle of the males. The electrodes were positioned slightly lower in the females. A third reference electrode was situated below the subject's right scapula. To minimize skin resistance and to improve conduction, the electrodes were treated with an electrolytic paste.

Initial (pre-exercise) heart rates. Before being tested on the bicycle ergometer, each subject rested for five minutes while seated on the bicycle seat. After this resting period, the subject's heart rate was recorded. The same procedure was followed before being tested on the treadmill, except in this instance, each subject rested on a chair beside the treadmill.

Equipment

Bicycle ergometer. The Sjostrand Physical Work Capacity Test was performed on a Swedish bicycle ergometer. An electrical counter was attached to an elliptical band on the pedal axis. As the pedals revolved, a microswitch came into contact with the elliptical band once with each revolution. This triggered the counter and allowed the exact number of revolutions to be recorded.

Metronome. An electric metronome was used to aid the subjects in maintaining a pedalling rate of sixty revolutions per minute.

Treadmill. The Modified Johnson Brouha Darling Test was performed on a motor driven treadmill which could be adjusted for speed and angle of inclination.

Calibration Procedure

Bicycle ergometer. The sinus balance was calibrated by means of a set of standard gram weights.

1. The brake drum was removed and the mark on the pendulum weight was set at zero.

2. A one-half kilogram weight was attached to the spring. If the pendulum mark coincided with the scale mark, no supplementary imprints were needed. If however the scale mark and the pendulum mark did not coincide, an accessory line was placed on the scale, to indicate the correct pendulum position for that weight.

3. This procedure was repeated for each quarter scale marking.

Treadmill. The incline of the treadmill bed was calibrated by a level connected to a metal rod. When this instrument was placed on the treadmill bed, it indicated the correct grade, measured in percentage. It was then possible

to raise or lower the treadmill bed until the desired grade was reached.

The speed of the treadmill was measured by counting the number of revolutions of the treadmill belt in one minute. The calculated speed in miles per hour could then be used to calibrate the speedometer reading. Previous calibration in this laboratory had shown that treadmill speed was constant for rates of speed from one to seven miles per hour.

Test Procedures

Modified Johnson Brouha Darling Test (60).

1. The subject rested for five minutes in a sitting position while the electrodes were attached. After five minutes his heart rate was recorded.

2. The subject warmed up by walking uphill for five minutes at a speed of 3.5 miles per hour and a grade of 8.6 per cent. After walking 4½ minutes, his heart rate was recorded.

3. The subject then rested on a chair for five minutes, during which time his heart rate was monitored. Thirty seconds before the end of the rest period, and anticipatory pre-run heart rate was registered.

4. At a signal, the subject ran at a speed of seven miles per hour, at the same grade of 8.6 per cent. The

subject was instructed to run until exhausted, and that the longer he ran, the better would be his score. No further motivation was provided. It was noted however that great rivalry developed among the subjects. When the subject could run no longer, he notified the tester who stopped the treadmill.

5. The time of the run was recorded in seconds and the subject's heart rate recorded. The maximum heart rate reading was made the second after the treadmill stopped. As the heart rate of man decreases an average of one beat per minute for ten seconds after the cessation of exercise, Cotton and Dill (28) as well as Sedgwick (79) found this to be an accurate method of measuring exercise heart rate.

6. After the run, the subject was seated. Heart rates were recorded from 1 to 1½, 2 to 2½, and 4 to 4½ minutes of recovery.

7. The fitness index was calculated by using the formula:

$$\frac{100 \times \text{duration of run in seconds}}{2 \times (\text{sum of three 30 second pulse rates from 1 to } 1\tfrac{1}{2},\ 2 \text{ to } 2\tfrac{1}{2},\ 4 \text{ to } 4\tfrac{1}{2} \text{ minutes recovery}).}$$

The run to exhaustion was a modification of the original test. Sedgwick (79) found that fit subjects had little trouble running the five minutes of the original test. These subjects were differentiated with regard to fitness score

solely in terms of recovery heart rate. Because of the overdependence of previous submaximal tests on recovery heart rate values, the modified test utilizing a maximum run was employed in this study.

<u>Sjostrand Physical Work Capacity Test</u>.

1. The bicycle seat was adjusted for each subject. It was positioned so that, when the subject was seated with the ball of his foot on the pedal, at the bottom of its rotation, his knee was flexed in such a way that an imaginary straight line could be drawn from the subject's knees perpendicular to his toes.

2. The subject rested for five minutes on the bicycle while the electrodes and leads were attached, and heart rate recorded.

3. An electric metronome was started. This provided the rhythm to aid the subject in pedalling at a rate of sixty revolutions per minute.

4. The test consisted of pedalling on a bicycle ergometer continuously for eighteen minutes. Every subject pedalled at three work loads, each of six minutes duration. Where possible, the work loads were set so that the heart rate for the first work load was between 115 to 130 beats per minute, for the second work load, between 130 to 150 beats per minute and for the third, between 150 to 170 beats per minute.

5. After the five minute rest period, the subject began pedalling, in time to the metronome, at a rate of sixty revolutions per minute. At this time the desired work level was set by adjusting the friction belt, and the counter and stopwatch were started.

6. The heart rate was recorded on an E.C.G. after each minute of the test. Work load and number of revolutions pedalled were recorded at the end of the sixth, twelfth and eighteenth minute of the test. New work loads were set at the beginning of the seventh and thirteenth minutes.

7. At the end of the eighteenth minute, the subject stopped pedalling.

8. By using heart rate and work load values, the physical work capacity at a heart rate of 170 beats per minute was calculated for each subject by using a regression analysis.

Statistical Analysis

The following were treated using an analysis of variance to determine whether significant changes had occurred throughout the training period:

1. PWC scores.
2. Physical Fitness Indexes.
3. Performance times.
4. Initial heart rates.
5. Walking heart rates.

6. Anticipatory heart rates.

7. Maximal heart rates.

The data was treated using a two way analysis of variance with repeated measures. The analysis of variance outlined by Winer (91:376) was employed to treat the scores of the three groups of swimmers. The computation of the analysis of variance was accomplished by the use of an APL program. The computer used was an IBM 360/67 installed in the Computer Science Department at the University of Alberta.

Where the analysis of variance indicated significant differences among tests, a Scheffe Test (40:296) was used to determine which trials were significantly different.

A correlation matrix was computed between PWC scores, Physical Fitness Indexes, performance times and body weights. Then the predictable variance was calculated at each of the three testing sessions.

CHAPTER IV

RESULTS AND DISCUSSION

I. RESULTS

Subjects

At the time of the first test, data was obtained for fifty-four swimmers. During the course of the training period, twelve subjects left their respective teams and ceased practicing. Three other swimmers, in the opinion of their coaches, had only trained infrequently and were also eliminated from the study. The subjects thus consisted of thirty-nine actively training swimmers. Group I was comprised of nine university males, Group II was made up of sixteen teenage males and Group III of fourteen teenage females.

Physical characteristics. The means, standard deviations and ranges for age, height and weight of the three groups are presented in Tables I, II, III. In these tables, the mean age and height of each group, measured at the time of the first test, is recorded. In addition, the mean group weights obtained at each of the three testing periods, are registered. Data for each subject are contained in Appendix B. Group I, as a group, was older, taller and heavier than either Group II or Group III. The mean ages

TABLE I

MEANS, STANDARD DEVIATIONS AND RANGES FOR AGE, HEIGHT AND WEIGHT, FOR GROUP I
N = 9

Statistic	Unit	Time of measurement	Mean	Standard deviation	Range
Age	Years	Before Test One	20.61	2.39	16.8 - 24.4
Height	Centimeters	Before Test One	179.99	5.30	175.19 - 192.96
Weight	Kilograms	Before Test One	72.78	8.42	54.89 - 83.47
Weight	Kilograms	Before Test Two	71.62	8.10	55.34 - 81.19
Weight	Kilograms	Before Test Three	72.12	7.31	56.25 - 78.93

TABLE II

MEANS, STANDARD DEVIATIONS AND RANGES FOR AGE, HEIGHT AND WEIGHT, FOR GROUP II
N = 16

Statistic	Unit	Time of measurement	Mean	Standard deviation	Range
Age	Years	Before Test One	14.83	1.27	12.7 - 18.0
Height	Centimeters	Before Test One	171.70	8.64	154.88 - 190.43
Weight	Kilograms	Before Test One	60.64	11.26	42.18 - 79.38
Weight	Kilograms	Before Test Two	60.50	10.38	42.18 - 77.11
Weight	Kilograms	Before Test Three	61.49	9.66	43.55 - 78.02

TABLE III

MEANS, STANDARD DEVIATIONS AND RANGES FOR AGE,
HEIGHT AND WEIGHT FOR GROUP III
N = 14

Statistic	Unit	Time of measurement	Mean	Standard deviation	Range
Age	Years	Before Test One	15.01	1.20	13.0 - 16.9
Height	Centimeters	Before Test One	164.31	6.09	157.42 - 177.73
Weight	Kilograms	Before Test One	56.41	6.19	41.73 - 64.41
Weight	Kilograms	Before Test Two	56.12	5.97	42.64 - 64.41
Weight	Kilograms	Before Test Three	56.21	5.72	44.91 - 63.96

for Group II and III were similar, 14.83 years for Group II and 15.01 years for Group III. Group II however, as a group, was taller and heavier than Group III.

Physical Work Capacity

The means, standard deviations, and ranges of PWC_{170} for the three groups at each of the three testing sessions are presented in Table IV. The changes in PWC_{170} throughout the training period are illustrated in Figure I (p.51). The data for individual subjects is contained in Appendic C.

In all three groups, mean PWC_{170} values decreased from test one to test two. In Group I there was a further decrease from test two to test three. In Groups II and III however, mean PWC_{170} scores increased from test two to test three, to values greater than those obtained on test one.

The percentage changes between these means are outlined in Table V. In this table, the changes in PWC_{170} between successive tests are recorded for each group. Percentage changes in PWC_{170} mean values range from -4.62 percent to +14.43 percent. The negative values indicate decreases in PWC_{170} scores between tests, and inferior work capacity, while the positive values indicate increases in work capacity and superior PWC_{170} scores.

Mean work capacity differences among tests and among groups. A two way analysis of variance with repeated measures (91:376) was used to test for significant difference

TABLE IV

MEANS, STANDARD DEVIATIONS AND RANGES FOR PWC_{170} MEASURED AT THREE TESTING SESSIONS FOR THREE SUBJECT GROUPS EXPRESSED IN KPM/MIN.

Statistic	Group I			Group II			Group III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	1326.8	1321.9	1265.4	951.1	935.3	1026.5	706.0	694.0	807.9
Standard Deviation	241.6	200.8	203.0	248.0	246.5	238.7	183.6	210.1	144.4
Range	999.6 - 1657.9	979.0 - 1689.4	908.1 - 1532.1	560.8 - 1368.6	595.3 - 1329.8	678.3 - 1388.9	460.4 - 1058.5	372.6 - 1028.3	632.9 - 1052.8

TABLE V

PERCENTAGE CHANGE IN PWC_{170} SCORES THROUGHOUT A SEASON OF TRAINING

GROUP	GROUP I			GROUP II			GROUP III		
Between Tests	1-2	2-3	1-3	1-2	2-3	1-3	1-2	2-3	1-3
Percent Change	-.36	-4.27	-4.62	-1.66	+9.75	+7.92	-1.69	+16.41	+14.43

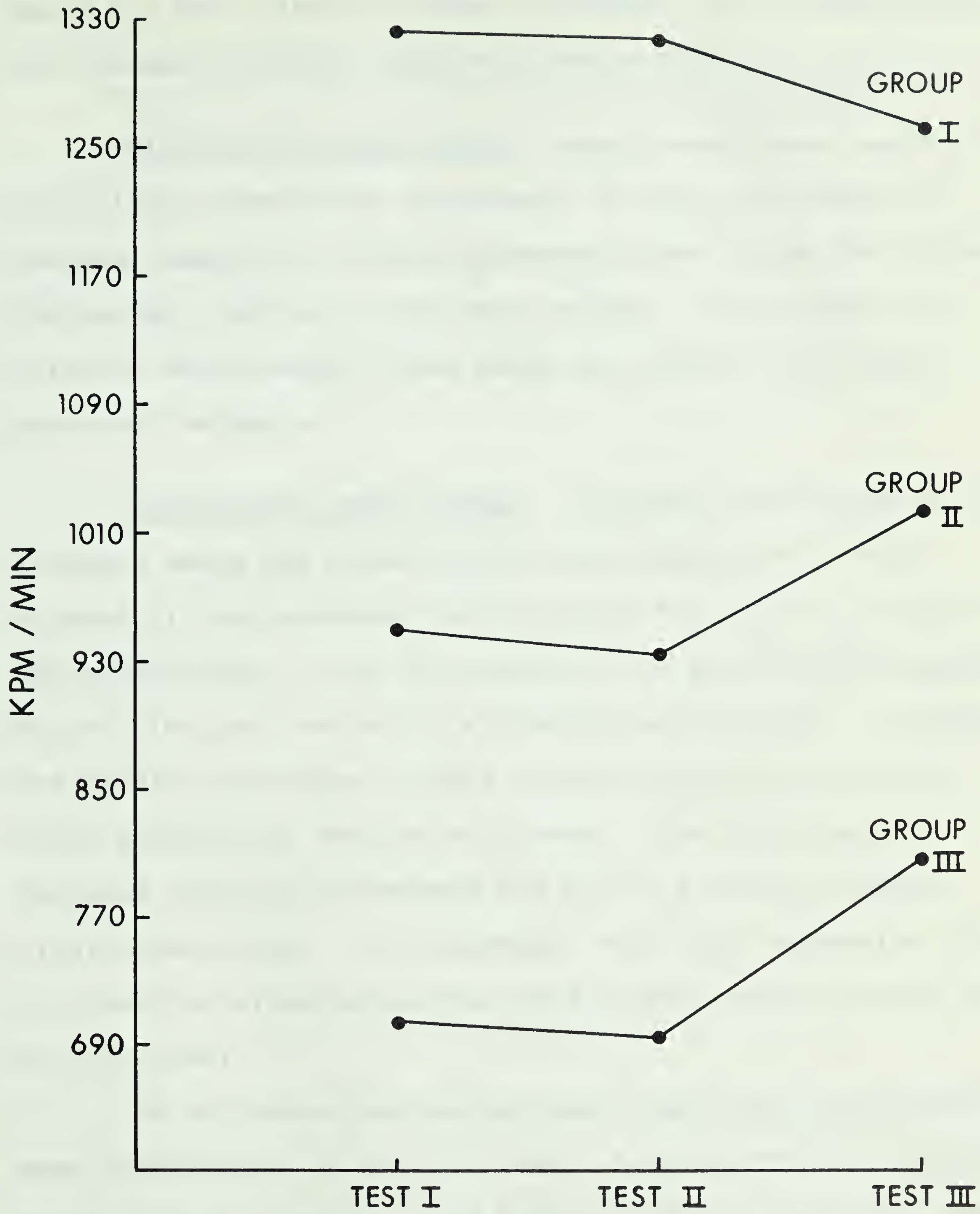

FIGURE 1

CHANGES IN PWC 170 THROUGHOUT A SEASON OF TRAINING FOR THREE GROUPS OF SWIMMERS

among the work capacity means. A summary of the results of the variance analysis appears in Table VI.

Differences among tests. Among tests, there was no significant statistical difference in means expressed in kpm/min, measured at three different times during the training period, for any of the three groups. Significant differences were however found among the means of the three groups of swimmers.

Differences among groups. Although significant differences among the means of the three groups were demonstrated, it was necessary to determine the exact location of the significance. For this purpose, two means were compared at one time, by the use of a Scheffe Test (40:295). Because the Scheffe technique is more rigorous than other methods, fewer significant results will occur. For this reason, Ferguson (40:297) recommends the use of a less stringent significance level. In accordance with this suggestion, the .10 level of significance was used in this study instead of the .05 level.

At all three testing periods, there were significant mean differences, at the .10 level, between Groups I and II, between Groups II and III, and between Groups I and III. These results are outlined in Tables VII, VIII and IX (p.54). In these tables, the mean differences between pairs of groups

TABLE VI

ANALYSIS OF VARIANCE OF THE SJOSTRAND PWC_{170} TEST MEANS MEASURED AT THREE TIMES DURING THE TRAINING SEASON GROUP I, N=9, GROUP II, N=16, GROUP III, N=14 EXPRESSED IN KPM/MIN.

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	5,316,142.92	2	2,658,071.46	56.37	$<.001$
Among Tests	94,930.10	2	47,465.05	1.01	$>.05$
Interaction	113,213.48	4	28,303.37	6.02	$>.05$
Error	5,092,936.00	108	47,156.81		
Total	10,617,222.50	116			

TABLE VII

SCHEFFE TEST FOR BETWEEN GROUP MEANS ON TEST ONE OF PWC_{170}

Group I	Group II	Group III	Mean Difference	Critical F	Calculated F
1236.8		706.0	620.8*	4.92	44.77
	951.1	706.0	245.1*	4.92	9.51
1236.8	951.1		285.7*	4.92	9.97

TABLE VIII

SCHEFFE TEST FOR BETWEEN GROUP MEANS ON TEST TWO OF PWC_{170}

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
1321.9		694.0	627.9*	4.92	45.80
	935.3	694.0	241.3*	4.92	9.22
1321.9	935.3		386.6*	4.92	18.26

TABLE IX

SCHEFFE TEST FOR BETWEEN GROUP MEANS ON TEST THREE OF PWC_{170}

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
1265.4		807.9	457.5*	4.92	24.32
	1026.5	807.9	218.6*	4.92	7.57
1265.4	1026.5		238.9*	4.92	6.97

*Significant at the .10 level

are listed. An asterisk signifies that the mean differences between two groups was significant at the .10 level of confidence.

Physical work capacity per kilogram of body weight. In order to compare the work capacities of different populations and to compare the results of different investigations, it is useful to express work capacity as PWC/Kg. of body weight. The means, standard deviations and ranges for PWC/Kg. of body weight are presented in Table X.

Physical Fitness Index

Changes in fitness index. The means, standard deviations and ranges for physical fitness index measured at three times during the training season are presented in Table XI (p.57). For all three groups, there was an increase in mean fitness index from test one to test two, and from test two to test three. These mean changes are illustrated in Figure 2 (p.58).

In Table XII (p.57), mean changes, expressed in percentages, are outlined. Mean fitness indexes increased over a range from 1.54 to 69.0 percent.

Mean fitness index differences among tests and among groups. The results of the analysis of variance performed on fitness index scores are summarized in Table XIII (p.59).

TABLE X

MEANS, STANDARD DEVIATIONS AND RANGES FOR PWC_{170}/Kg. OF BODY WEIGHT AT THREE TESTING SESSIONS FOR THREE SUBJECT GROUPS

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	18.26	18.47	17.49	15.60	15.33	16.59	12.46	12.25	14.33
Standard Deviation	2.61	2.19	1.63	2.46	2.38	2.18	2.58	3.10	1.72
Range	12.77 - 21.14	15.59 - 23.28	15.81 - 20.60	10.92 - 19.77	11.81 - 21.09	12.78 - 20.55	8.06 - 16.43	8.13 - 17.57	11.58 - 17.33

TABLE XI

MEANS, STANDARD DEVIATIONS AND RANGES FOR PHYSICAL FITNESS INDEX MEASURED AT THREE TESTING SESSIONS FOR THREE SUBJECT GROUPS

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	70.1	110.1	111.8	55.8	68.2	94.3	26.1	31.9	37.3
Standard Deviation	34.7	58.9	53.3	22.7	21.7	29.9	7.8	10.6	10.7
Range	32.0 - 129.4	59.3 - 196.3	57.8 - 226.4	16.9 - 113.2	40.0 - 120.6	55.9 - 156.6	15.1 - 42.9	16.8 - 50.7	21.3 - 56.4

TABLE XII

PERCENTAGE CHANGE IN FITNESS INDEX SCORES THROUGHOUT A SEASON OF TRAINING

GROUP	GROUP I			GROUP II			GROUP III		
Between Tests	1-2	2-3	1-3	1-2	2-3	1-3	1-2	2-3	1-3
Percent Change	+57.06	+1.54	+59.49	+22.22	+38.27	+69.00	+22.22	+16.93	+42.91

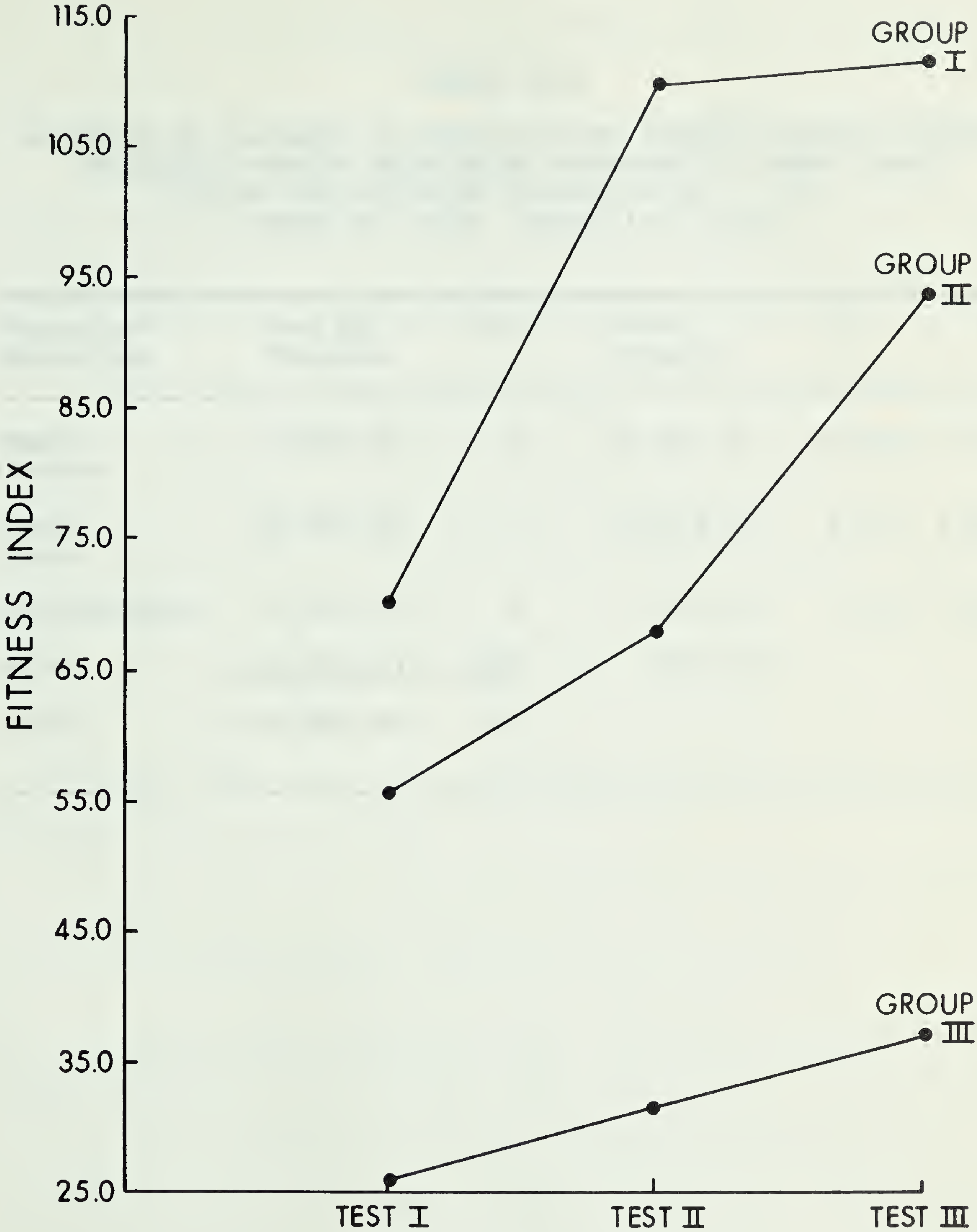

FIGURE 2

CHANGES IN FITNESS INDEX THROUGHOUT A SEASON OF TRAINING FOR THREE GROUPS OF SWIMMERS

TABLE XIII

ANALYSIS OF VARIANCE OF THE MODIFIED JOHNSON BROUHA DARLING PHYSICAL FITNESS TEST MEANS MEASURED AT THREE TIMES DURING THE TRAINING SEASON GROUP I, N=9, GROUP II, N=16, GROUP III, N=14

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	77,250.42	2	38,625.21	45.34	$<.001$
Among Tests	16,944.00	2	8,472.00	9.95	$<.001$
Interaction	6,291.49	4	1,572.87	1.85	$>.05$
Error	91,996.73	108	851.82		
Total	192,482.64	116			

Significant differences occurred among tests as well as among groups.

Differences between tests. The Scheffe Test was again employed to examine the differences between pairs of means. The results of the mean fitness index differences between tests are summarized in Tables XIV, XV, and XVI.

For Group I, there was a significant difference in fitness index means between tests one and two and between tests one and three. The significances occurred at the .10 level. There was no significant differences between tests two and three.

For Group II, significant mean differences were present between tests one and three and between tests two and three. There were no significant differences however between tests one and two.

For Group III, there were no significant mean fitness index differences among tests.

Differences between groups. The mean differences between groups are outlined in Tables XVII, XVIII and XIX (p.62).

On the first test, means differed significantly between the male and female groups, but did not differ significantly between the two male groups. That is, there were significant differences between Groups I and III and between Groups II and III, but not between Groups I and II.

TABLE XIV

SCHEFFE TEST FOR BETWEEN TEST PHYSICAL FITNESS MEANS FOR GROUP I

Test 1	Test 2	Test 3	Mean Difference	Critical F	Calculated F
70.1		111.8	41.7*	5.08	9.19
	110.1	111.8	1.7NS	5.08	.02
70.1	110.1		40.0*	5.08	8.45

TABLE XV

SCHEFFE TEST FOR BETWEEN TEST PHYSICAL FITNESS MEANS FOR GROUP II

Test 1	Test 2	Test 3	Mean Difference	Critical F	Calculated F
55.8		94.3	38.5*	4.84	13.92
	68.2	94.3	26.1*	4.84	6.40
55.8	68.2		12.4NS	4.84	1.44

TABLE XVI

SCHEFFE TEST FOR BETWEEN TEST PHYSICAL FITNESS MEANS FOR GROUP III

Test 1	Test 2	Test 3	Mean Difference	Critical F	Calculated F
26.1		37.3	11.2NS	4.90	1.03
	31.9	37.3	5.4NS	4.90	.24
26.1	31.9		5.8NS	4.90	.28

*Significant at the .10 level
NS Not significant at the .10 level

TABLE XVII

SCHEFFE TEST FOR BETWEEN GROUP MEANS ON
TEST ONE OF PHYSICAL FITNESS INDEX

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
70.1		26.1	44.0*	4.92	12.45
	55.8	26.1	29.1*	4.92	7.42
70.1	55.8		14.3NS	4.92	1.38

TABLE XVIII

SCHEFFE TEST FOR BETWEEN GROUP MEANS ON
TEST TWO OF PHYSICAL FITNESS INDEX

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
110.1		31.9	78.2*	4.92	39.33
	68.2	31.9	36.3*	4.92	11.55
110.1	68.2		41.9*	4.92	11.87

TABLE XIX

SCHEFFE TEST FOR BETWEEN GROUP MEANS ON
TEST THREE OF PHYSICAL FITNESS INDEX

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
111.8		37.3	74.5*	4.92	35.70
	94.3	37.3	57.0*	4.92	28.48
111.8	94.3		17.5NS	4.92	2.07

*Significant at the .10 level
NS Not significant at the .10 level

On the second test, there were significant mean differences among all three groups.

Again, on test three, there were differences between the males and females, but not between the two male groups. Groups I and II differed significantly from Group III. Group I however did not differ significantly from Group II.

Physical fitness index per kilogram of body weight. Physical fitness index was divided by body weight measured in kilograms. These values were then multiplied by ten to allow scores to be expressed in whole numbers. The means, standard deviations and ranges for these values are presented in Table XX.

Performance Times

In considering the changes in swim times during the training season, it must be recalled that Group I was timed for 100 yards freestyle while Groups II and III were tested for 100 meters freestyle. The distance swum was therefore slightly less for Group I than it was for Groups II and III.

Changes in swim times. All groups decreased mean swim times, and therefore improved performance from test one to test two. Groups I and III decreased swim times further from test two to test three. The performance time for Group II was the same for tests two and three. The means,

TABLE XX

MEANS, STANDARD DEVIATIONS AND RANGES FOR PHYSICAL FITNESS INDEX/Kg. OF BODY WEIGHT X 10 MEASURED AT THREE TESTING SESSIONS FOR THE THREE SUBJECT GROUPS

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	9.72	15.55	15.50	9.32	11.52	15.49	4.61	5.62	6.62
Standard Deviation	4.92	8.47	7.18	3.62	3.80	4.48	1.15	1.59	1.67
Range	4.13 - 18.89	7.56 - 27.06	8.41 - 30.43	3.13 - 15.90	6.13 - 18.36	9.57 - 23.17	2.78 - 6.60	3.22 - 8.04	3.59 - 9.56

standard deviations and ranges of these swim times are displayed in Table XXI. The mean changes are also illustrated in Figure 3 (p.67).

When performance improves, swim times decrease. As a result, when swim time means are expressed in terms of percentage changes, they appear as negative percentages. These percentage changes are listed in Table XXII. Percentage change values ranged from 0 to -3.04.

Mean performance time differences among tests and among groups. By the use of an analysis of variance on the swim time scores, it was possible to determine that there were no significant differences among swim tests over a season of training. There were however significant differences noted among the three groups. These results are summarized in Table XXIII (p.68).

Differences between groups. A Scheffe Test was then used to compare pairs of group means. On test one, significant mean differences were demonstrated between Groups I and II, between Groups II and III, and between Groups I and III. These differences were significant at the .10 level.

On the second and third performance tests, significant mean differences also occurred between the same pairs of groups. These outcomes are outlined in Tables XXIV, XXV and XXVI (p.69).

TABLE XXI

MEANS, STANDARD DEVIATIONS AND RANGES FOR 100 YARD AND METER FREESTYLE TIMES MEASURED AT THREE TIMES DURING THE SEASON EXPRESSED IN SECONDS

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	59.2	58.4	58.2	69.4	67.5	67.5	75.6	74.5	73.3
Standard Deviation	4.7	4.8	3.1	6.1	5.3	5.6	7.0	6.3	6.4
Range	53.5 - 68.7	52.8 - 68.6	54.2 - 64.1	56.8 - 77.2	57.0 - 77.1	56.7 - 77.5	64.4 - 87.4	63.9 - 85.8	64.0 - 85.6

TABLE XXII

PERCENTAGE CHANGE IN SWIM TIMES THROUGHOUT A SEASON OF TRAINING

GROUP	GROUP I			GROUP II			GROUP III		
Between Tests	1-2	2-3	1-3	1-2	2-3	1-3	1-2	2-3	1-3
Percent Change	-1.35	-.34	-1.69	-2.74	0	-2.74	-1.46	-1.61	-3.04

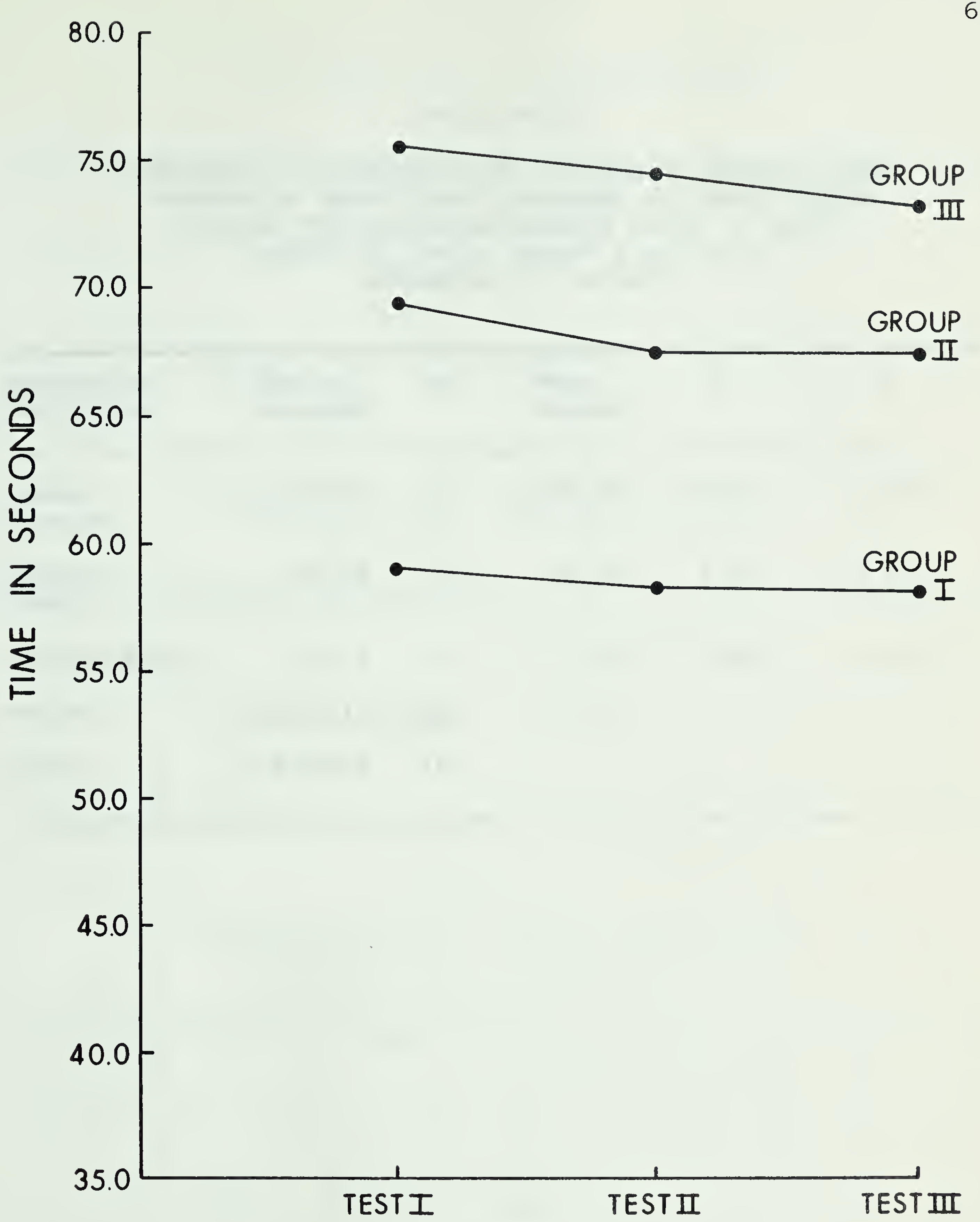

FIGURE 3

CHANGES IN SWIM TIMES THROUGHOUT A SEASON OF TRAINING FOR THREE GROUPS OF SWIMMERS

TABLE XXIII

ANALYSIS OF VARIANCE OF 100 METER AND 100 YARD FREESTYLE MEAN TIMES OBTAINED AT THREE TIMES DURING THE TRAINING SEASON GROUP I, N=9 GROUP II, N=16, GROUP III, N=14 EXPRESSED IN SECONDS

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	4,153.74	2	2,076.87	62.67	$<.001$
Among Tests	70.59	2	35.30	1.07	$>.05$
Interaction	11.14	4	2.78	.08	$>.05$
Error	3,579.37	108	33.14		
Total	7,814.84	16			

TABLE XXIV

SCHEFFE TEST FOR BETWEEN GROUP MEANS
ON TEST ONE OF FREESTYLE SWIM

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
59.2		75.6	16.4*	4.92	44.46
	69.4	75.6	6.2*	4.92	8.66
59.2	69.4		10.2*	4.92	18.09

TABLE XXV

SCHEFFE TEST FOR BETWEEN GROUP MEANS
ON TEST TWO OF FREESTYLE SWIM

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
58.4		74.5	16.1*	4.92	42.84
	67.5	74.5	7.0*	4.92	11.04
58.4	67.5		9.1*	4.92	14.40

TABLE XXVI

SCHEFFE TEST FOR BETWEEN GROUP MEANS
ON TEST THREE OF FREESTYLE SWIM

GROUP I	GROUP II	GROUP III	Mean Difference	Critical F	Calculated F
58.2		73.3	15.1*	4.92	37.69
	67.5	73.3	5.8*	4.92	7.57
58.2	67.5		9.3*	4.92	15.04

* Significant at the .10 level

It is not surprising that there are differences among groups, especially between Group I and the other groups, since Group I swam a shorter distance.

Relationships Between Changes in Each Group

Group I. The changes in PWC_{170}, fitness index and performance time for Group I are illustrated in Figure 4 (p.71). In this Figure as in Figures 5 and 6 (p.76, 80), the units on the horizontal axis are common to all three variables. There are however three vertical axes, one corresponding to each variable. Because of this, there are three different kinds of units represented, one kind of unit being represented on each vertical axis. In other words, PWC_{170} scores are represented on one vertical axis, fitness index scores on another vertical axis and performance times on the third.

As PWC_{170} and fitness index improve, there is an increase in the actual score attained. The reverse is true with regard to performance time. As performance improves, swim times decrease.

It can thus be seen that as fitness index and performance time improved during the training season, work capacity deteriorated. While mean changes occurred in all three variables, it must be recalled that the only statistically significant changes were between test one and test two and between tests one and three of fitness index.

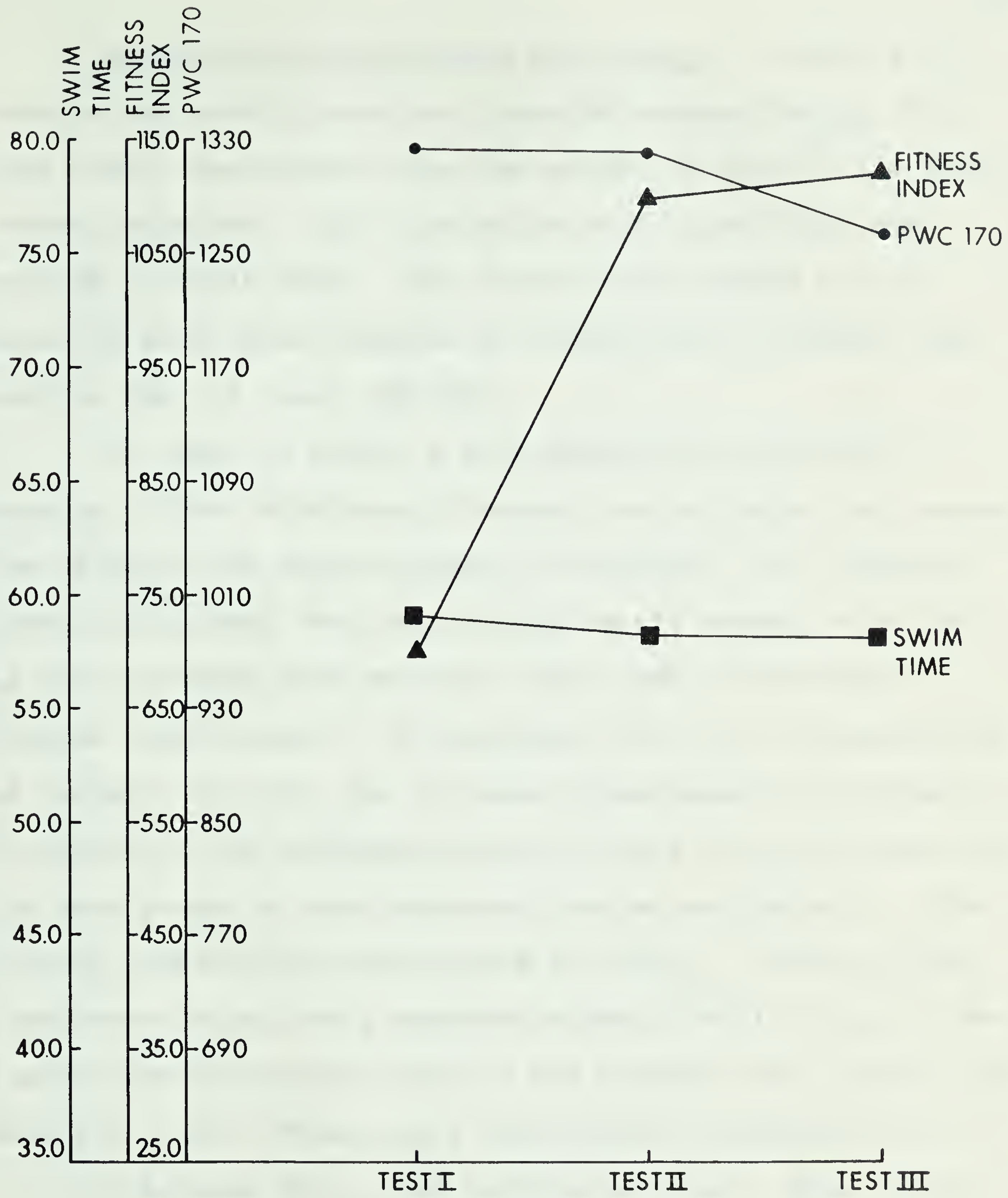

FIGURE 4

CHANGES IN PWC 170 FITNESS INDEX AND PERFORMANCE TIME THROUGHOUT A SEASON OF TRAINING
GROUP I

<u>Correlation coefficients for Group I</u>. A matrix of correlation coefficients was computed between PWC_{170}, fitness index, performance time and weight at each of the three testing sessions. The correlation coefficients are summarized in Table XXVII. The correlations marked with an asterisk were those found to be significantly greater than zero at the .05 level (88:259).

In order to obtain a more meaningful and stable measure of the relationship between the variables, an average was taken of the various pairs of variables. All correlations, both those that were significantly greater than zero as well as those that were not, were used to determine average correlations. In accordance with the recommendation of Garrett (44:173), the r's were transformed into Fisher's z function. The arithmetic mean of the z's was obtained and the mean z was in turn converted into an equivalent r. The average correlation coefficients for PWC_{170}, fitness index, performance time, are presented in Table XXVIII (p.74). The highest correlation for Group I was between work capacity and weight r = .68. There was a low negative correlation of r = −.23 between PWC_{170} and performance time. This correlation was not however significantly greater than zero at the .05 level.

<u>Predictable variances for Group I</u>. In terms of explained variance (see p.14) 5.29 percent of the variance

TABLE XXVII

MATRIX OF CORRELATION COEFFICIENTS BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT AT THREE TEST SESSIONS FOR GROUP I

Variable	PWC_1	PWC_2	PWC_3	$F.I._1$	$F.I._2$	$F.I._3$	$P.T._1$	$P.T._2$	$P.T._3$	$Wt._1$	$Wt._2$	$Wt._3$
PWC_1	1.0	.902*	.859*	.163	.322	.423	-.672*	-.366	-.351	.514	.486	.608
PWC_2		1.0	.954*	.295	.420	.655	-.326	.054	-.003	.707*	.596	.717*
PWC_3			1.0	.161	.245	.490	-.244	.096	.125	.781*	.709*	.830*
Fitness Index $_1$				1.0	.939*	.794*	-.006	.135	.067	.010	-.141	-.032
Fitness Index$_2$					1.0	.841*	-.167	.041	-.108	.094	-.061	.026
Fitness Index$_3$						1.0	-.017	.286	.099	.265	.038	.169
Performance Time $_1$							1.0	.913*	.896*	.083	.005	-.077
Performance Time $_2$								1.0	.900*	.401	.263	.211
Performance Time $_3$									1.0	.319	.227	.204
Weight $_1$										1.0	.966*	.963*
Weight $_2$											1.0	.973*
Weight $_3$												1.0

*Significantly greater than zero at the .05 level

TABLE XXVIII

AVERAGE OF THE CORRELATION COEFFICIENTS BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT FOR GROUP I

Variable	Fitness Index	Performance Time	Weight
PWC_{170}	.36	-.23	.68*
Fitness Index		.04	.03
Performance Time			.18

*Significantly greater than zero at the .05 level

TABLE XXIX

AMOUNT OF EXPLAINED VARIANCE BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT EXPRESSED IN PERCENTAGE FOR GROUP I

Variable	Fitness Index	Performance Time	Weight
PWC_{170}	12.96	5.29	46.24
Fitness Index		.16	.09
Performance Time			3.24

of performance time is predictable from the variance of PWC_{170} and .16 percent of the variance of performance time is predictable from the variance of fitness index for Group I. The percentage of explained variance values for Group I are presented in Table XXIX (p.74).

Group II. The changes in PWC_{170}, fitness index and performance time for Group II are illustrated in Figure 5. Over the entire season, there was a mean improvement on all three variables. There was however a drop in mean PWC_{170} from test one to test two, and a levelling off of performance time from the second to third test. The only statistically significant changes occurred on fitness index between tests one and three and between tests two and three.

Correlation coefficients. A matrix of correlation coefficients was computed between PWC_{170}, fitness index, performance time and weight. These are outlined in Table XXX (p.77). These correlation coefficients were averaged and appear in Table XXXI (p.78). Of greatest interest are the correlations between performance times and the tests of work capacity and physical fitness. Between performance time and PWC_{170} $r = -.61$ and between performance time and fitness index $r = -.51$. This means that as work capacity and fitness index improved there was a tendency for performance time to improve concurrently.

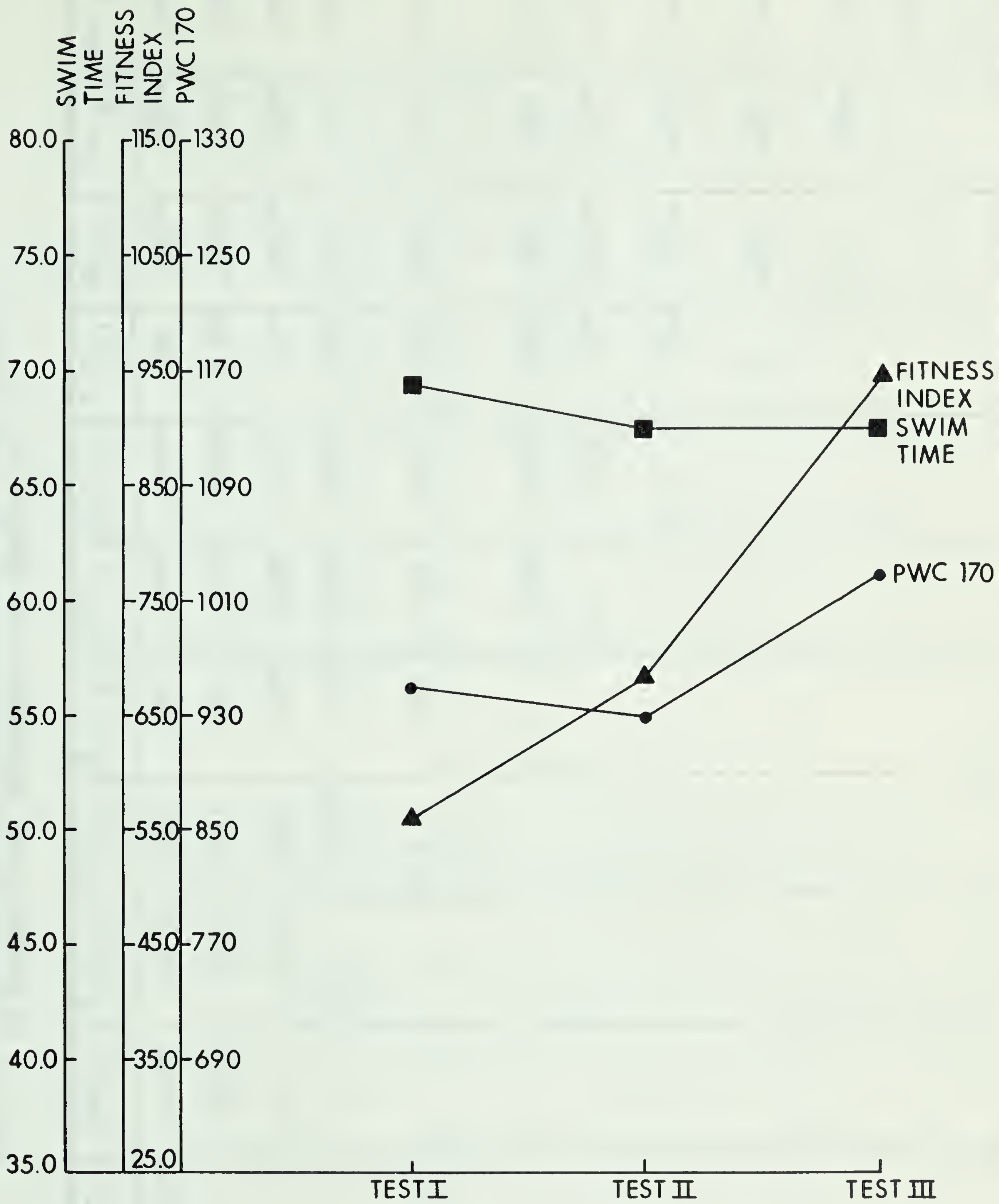

FIGURE 5

CHANGES IN PWC 170 FITNESS INDEX AND PERFORMANCE TIME THROUGHOUT A SEASON OF TRAINING

GROUP II

TABLE XXX

MATRIX OF CORRELATION COEFFICIENTS BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT AT THREE TEST SESSIONS FOR GROUP II

Variable	PWC_1	PWC_2	PWC_3	$F.I._1$	$F.I._2$	$F.I._3$	$P.T._1$	$P.T._2$	$P.T._3$	$Wt._1$	$Wt._2$	$Wt._3$
PWC_1	1.0	.814*	.851*	.429	.237	.390	-.525*	-.559*	-.464	.803*	.809*	.823*
PWC_2		1.0	.850*	.247	.181	.493	-.695*	-.680*	-.634*	.815*	.817*	.804*
PWC_3			1.0	.452	.322	.531*	-.645*	-.670*	-.571*	.830*	.829*	.850*
Fitness $Index_1$				1.0	.937*	.731*	-.544*	-.496	-.460	.225	.215	.268
Fitness $Index_2$					1.0	.790*	-.482	-.408	-.413	.090	.063	.101
Fitness $Index_3$						1.0	-.652*	-.539*	-.608*	.288	.249	.261
Performance $Time_1$							1.0	.934*	.912*	-.623*	-.597*	-.577*
Performance $Time_2$								1.0	.970*	-.603*	-.603*	-.602*
Performance $Time_3$									1.0	-.459	-.451	-.444
$Weight_1$										1.0	.988*	.959*
$Weight_2$											1.0	.987*
$Weight_3$												1.0

*Significantly greater than zero at the .05 level

TABLE XXXI

AVERAGE OF THE CORRELATION COEFFICIENTS BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT FOR GROUP II

Variable	Fitness Index	Performance Time	Weight
PWC_{170}	.37	-.61*	.82*
Fitness Index		-.51*	.20
Performance Time			-.55*

*Significantly greater than zero at the .05 level

TABLE XXXII

AMOUNT OF EXPLAINED VARIANCE BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT EXPRESSED IN PERCENTAGE FOR GROUP II

Variable	Fitness Index	Performance Time	Weight
PWC_{170}	13.69	37.21	67.24
Fitness Index		26.01	4.0
Performance Time			30.25

Predictable variances. In terms of explained variance, these correlation values correspond to 37.21 and 26.01 percent respectively. The explained variances between the other variables are summarized in Table XXXII (p.78).

Group III. The changes in PWC_{170}, fitness index and performance time for Group III are illustrated in Figure 6 (p.80). Over the season, there was a mean improvement in all three variables. There was a drop however in PWC_{170} mean score from test one to test two. Although there are obvious mean changes in all variables, there are no statistically significant changes in any of these three variables for Group III.

Correlation coefficients. A matrix of correlation coefficients was computed for Group III and appears in Table XXXIII. Average correlation coefficient values are presented in Table XXXIV (p.82). Relatively high correlation coefficients for Group III were demonstrated between performance time and fitness index, $r = -.73$ and between performance time and PWC_{170} $r = -.69$.

Predictable variances. In terms of explained variance, these values correspond to percentages of 53.29 and 47.61 respectively. These explained variances are outlined in Table XXXV (p.82).

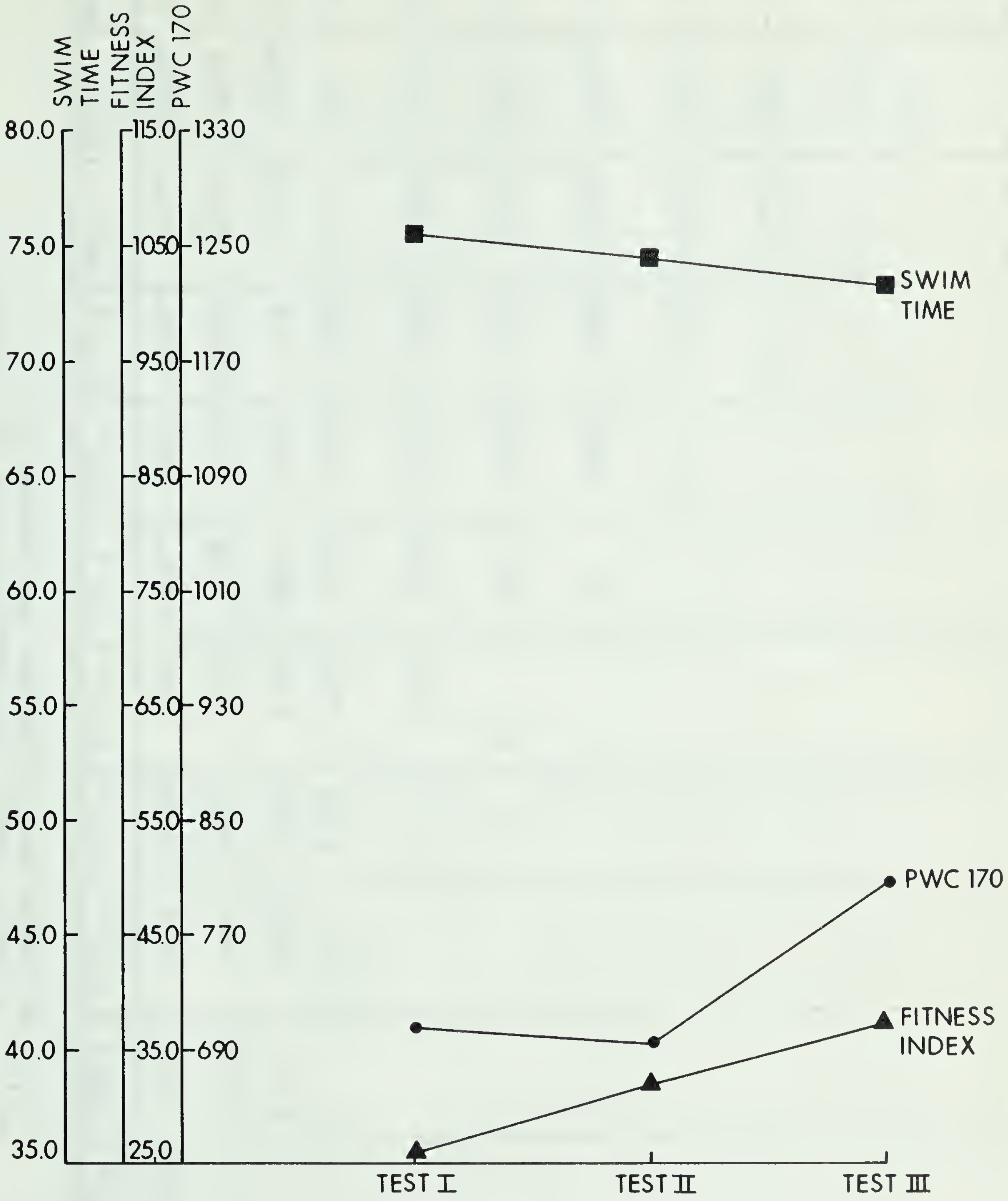

FIGURE 6

CHANGES IN PWC170 FITNESS INDEX AND PERFORMANCE TIME THROUGHOUT A SEASON OF TRAINING

GROUP III

TABLE XXXIII

MATRIX OF CORRELATION COEFFICIENTS BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT AT THREE TEST SESSIONS FOR GROUP III

Variable	PWC_1	PWC_2	PWC_3	$F.I._1$	$F.I._2$	$F.I._3$	$P.T._1$	$P.T._2$	$P.T._3$	$Wt._1$	$Wt._2$	$Wt._3$
PWC_1	1.0	.808*	.808*	.511	.566*	.428	-.655*	-.681*	-.581*	.617*	.632*	.676*
PWC_2		1.0	.823*	.436	.648*	.541*	-.769*	-.748*	-.686*	.621*	.625*	.688*
PWC_3			1.0	.612*	.733*	.639*	-.726*	-.722*	-.529	.737*	.772*	.747*
Fitness $Index_1$				1.0	.916*	.837*	-.651*	-.627*	-.488	.512	.482	.486
Fitness $Index_2$					1.0	.952*	-.837*	-.813*	-.694*	.597*	.567*	.606*
Fitness $Index_3$						1.0	-.811*	-.789*	-.734*	.413	.383	.435
Performance $Time_1$							1.0	.983*	.878*	-.632*	-.652*	-.698*
Performance $Time_2$								1.0	.873*	-.621*	-.636*	-.676*
Performance $Time_3$									1.0	-.364	-.345	-.468
$Weight_1$										1.0	.976*	.958*
$Weight_2$											1.0	.960*
$Weight_3$												1.0

*Significantly greater than zero at the .05 level

TABLE XXXIV

AVERAGE OF THE CORRELATION COEFFICIENTS BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT FOR GROUP III

Variable	Fitness Index	Performance Time	Weight
PWC_{170}	.58*	-.69*	.69*
Fitness Index		-.73*	.50
Performance Time			-.58*

*Significantly greater than zero at the .05 level

TABLE XXXV

AMOUNT OF EXPLAINED VARIANCE BETWEEN THE VARIABLES PWC_{170}, FITNESS INDEX, PERFORMANCE TIME AND WEIGHT EXPRESSED IN PERCENTAGE FOR GROUP III

Variable	Fitness Index	Performance Time	Weight
PWC_{170}	33.64	47.61	47.61
Fitness Index		53.29	25.0
Performance Time			33.64

Initial Pulse Rates

Pulse rates were recorded for each subject prior to the administration of the work capacity and fitness tests. Initial treadmill pulse rates were recorded prior to the administration of the fitness test while the subject was seated on a chair. Initial bicycle pulse rates were recorded prior to the work capacity test, while the subject was seated on a bicycle ergometer. Initial pulse rates appear to be quite variable. Mean fluctuations occurred between initial bicycle pulse rates and initial treadmill pulse rates, as well as among subject groups. Mean values are presented in Tables XXXVI and XXXVII.

Mean initial pulse rate differences among tests and among groups. It was revealed by the use of an analysis of variance that there were no statistically significant changes in either initial treadmill pulse rates or initial bicycle pulse rates over a season of training. There were however significant differences among the three groups. These results are summarized in Tables XXXVIII and XXXIX (p.85).

A Scheffe Test was performed to examine mean differences between the groups. For initial treadmill pulse rates, significant mean differences at the .10 level occurred, at test one among all groups, at test two between Groups I and III as well as between Groups II and III, while at test

TABLE XXXVI

MEANS, STANDARD DEVIATIONS AND RANGES FOR INITIAL TREADMILL PULSE RATES MEASURED AT THREE TESTING SESSIONS FOR THE THREE SUBJECT GROUPS EXPRESSED IN BEATS PER MINUTE

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	60.2	59.9	65.1	76.8	74.8	76.4	92.3	81.5	76.1
Standard Deviation	14.7	15.6	14.3	10.0	13.4	11.8	16.7	11.7	11.2
Range	47-84	43-87	47-84	59-97	55-91	55-98	62-113	57-98	55-91

TABLE XXXVII

MEANS, STANDARD DEVIATIONS AND RANGES FOR INITIAL BICYCLE PULSE RATES MEASURED AT THREE TESTING SESSIONS FOR THREE SUBJECT GROUPS EXPRESSED IN BEATS PER MINUTE

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	67.1	62	67.3	82.1	75.6	75.3	84.1	75.8	82.9
Standard Deviation	12.8	11.3	14.4	14.4	11.1	14.5	13.7	14.0	14.8
Range	52-87	51-80	51-85	58-118	61-100	55-105	50-100	53-98	62-100

TABLE XXXVIII

ANALYSIS OF VARIANCE OF THE INITIAL TREADMILL PULSE RATE MEANS TAKEN AT THREE TIMES DURING THE TRAINING SEASON GROUP I, N=9, GROUP II, N=16, GROUP III, N=14

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	7,680.52	2	3,840.26	22.35	$<.001$
Among Tests	594.58	2	297.29	1.73	$>.05$
Interaction	1,489.22	4	372.30	2.17	$>.05$
Error	18,553.34	108	171.79		
Total	28,317.14	116			

TABLE XXXIX

ANALYSIS OF VARIANCE OF THE INITIAL BICYCLE PULSE RATE MEANS TAKEN AT THREE TIMES DURING THE TRAINING SEASON GROUP I, N=9, GROUP II, N=16, GROUP III, N=14

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	4,130.94	2	2,065.47	11.20	$<.001$
Among Tests	908.22	2	454.11	2.46	$>.05$
Interaction	294.42	4	73.60	.39	$>.05$
Error	19,924.39	108	184.49		
Total	25,257.97	116			

three the only significant difference was between Groups I and III.

Walk Pulse Rates

Mean walk pulse rate values decreased for all three groups throughout the training season. The means, standard deviations and ranges are depicted in Table XL.

Mean walk pulse rate differences among tests and among groups. After performing an analysis of variance, it was observed that significant differences were present among groups as well as among testing sessions. The results of the analysis of variance are outlined in Table XLI, (p.88).

It was revealed by the use of the Scheffe Test that there were no significant decreases in mean walk pulse rate over the training season for Groups I and II. There were however significant decreases in mean walk pulse rate for Group III between tests one and two and between tests one and three. No significant differences occurred between tests two and three.

There were also statistically significant differences among groups at all three testing sessions. Group I had the lowest and Group III the highest walking pulse rate means.

Pre-Run Pulse Rates

Mean pre-run pulse rates were lowest for Group I and

TABLE XL

MEANS, STANDARD DEVIATIONS AND RANGES FOR WALK PULSE RATE MEASURED AT THREE TESTING SESSIONS FOR THREE SUBJECT GROUPS EXPRESSED IN BEATS PER MINUTE

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	124.4	121.1	116.6	141.6	136.1	135.6	163.9	152.1	147.9
Standard Deviation	7.97	8.21	11.7	10.5	10.0	13.3	12.2	17.8	15.3
Range	105-132	114-136	102-138	129-158	118-158	108-158	143-180	125-180	115-167

TABLE XLI

ANALYSIS OF VARIANCE OF WALK PULSE MEANS OBTAINED AT THREE TIMES DURING THE TRAINING SEASON GROUP I, N=9, GROUP II, N=16, GROUP III, N=14

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	19,291.58	2	9,645.79	61.21	$<.001$
Among Tests	2,093.90	2	1,046.95	6.64	$<.001$
Interaction	473.92	4	118.48	.75	$>.05$
Error	17,019.37	108	157.59		
Total	38,878.77	116			

highest for Group III at all testing sessions. For all three groups mean values decreased throughout the training season. The means, standard deviations and ranges are presented in Table XLII.

Mean pre-run pulse rate differences among tests and among groups. By the use of an analysis of variance, it was found that significant mean differences existed among groups and among tests. These results are contained in Table XLIII, (p.91).

By the use of the Scheffe Test it was determined that there were no statistically significant mean pre-run pulse rate decreases for Group I. For Group II there were significant decreases between tests one and two and between tests one and three. For Group III the only significant decrease was between the first and third tests.

At the time of test one, there were significant differences among all three groups. At the second test the only differences were between the males and the females, that is between Groups I and II, and between II and III. At the time of the third test the only significant difference was between Groups I and III.

Maximal Pulse Rates

Table XLIV (p.92), contains the means, standard deviations and ranges of maximal pulse rates for all three groups.

TABLE XLII

MEANS, STANDARD DEVIATIONS AND RANGES FOR PRE-RUN PULSE RATES AT THREE TESTING SESSIONS FOR THREE SUBJECT GROUPS EXPRESSED IN BEATS PER MINUTE

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	70.3	70.2	68.8	99.9	84.3	83.9	115.4	101.5	95.6
Standard Deviation	18.3	10.1	12.3	20.6	13.6	18.2	21.0	10.8	21.3
Range	43-99	54-86	54-82	72-136	65-107	60-122	80-153	83-115	68-150

TABLE XLIII

ANALYSIS OF VARIANCE OF PRE-RUN PULSE RATE MEANS OBTAINED ON THREE OCCASIONS DURING THE TRAINING SEASON GROUP I, N=9, GROUP II, N=16, GROUP III, N=14

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	19,486.16	2	9,743.08	32.95	$< .001$
Among Tests	4,361.66	2	2,180.83	7.37	$< .05$
Interaction	1,239.75	4	309.94	1.05	$> .05$
Error	31,936.34	108	295.71		
Total	57,023.91	116			

TABLE XLIV

MEANS, STANDARD DEVIATIONS, AND RANGES FOR MAXIMAL PULSE RATES MEASURED AT THREE TESTING SESSIONS FOR THREE SUBJECT GROUPS EXPRESSED IN BEATS PER MINUTE

Statistic	GROUP I			GROUP II			GROUP III		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Mean	171.4	175.4	178.8	182.8	185.8	186.6	182.4	184.3	183.4
Standard Deviation	8.47	9.99	12.9	9.3	8.5	8.3	7.1	6.5	11.4
Range	161-187	161-195	158-204	167-200	170-200	176-204	170-195	176-200	170-209

Mean differences among tests and among groups. It is seen from the summary of the analysis of variance in Table XLV that while no significant changes occurred in maximum pulse rate over the training season, there were significant differences among the groups.

For the first and second testing sessions, significant mean differences were demonstrated by means of the Scheffe Test, between the males and the females, that is between Groups I and III and between Groups II and III. At the time of the third test there were no significant differences among groups.

II. DISCUSSION

Weight

The mean weight of the university swimmers was comparable to the mean weights of other university teams studied by Watts (90). The mean weight of the swimming team was 72.12 kilograms while the mean weight of the judo team, in the Watts study, was 72.94 kilograms. The mean weight of the hockey team was higher at 75.75 kilograms.

The mean weight of the teenage swimmers was greater than the mean weight of the thirteen to seventeen year olds reported in the C.A.H.P.E.R. study (24). The mean weight of the thirteen to seventeen year old C.A.H.P.E.R. study males was 57.57 kilograms. The mean weight of the male teenage

TABLE XLV

ANALYSIS OF VARIANCE OF MAXIMAL PULSE RATE MEANS OBTAINED ON THREE OCCASIONS DURING THE TRAINING SEASON GROUP I, N=9, GROUP II, N=16, GROUP III, N=14

Source of Variation	Sum of Squares	df	Mean Square	F	P
Among Groups	1,752.63	2	876.31	10.52	$<.001$
Among Tests	278.63	2	139.32	1.67	$>.05$
Interaction	117.22	4	29.30	.35	$>.05$
Error	8,997.44	108			
Total	11,145.92	116			

swimmers was 61.49 kilograms. Similarly, the female swimmers were heavier than a randomly selected population of Canadian girls of a comparable age. The mean weight of the thirteen to seventeen year old C.A.H.P.E.R. study females was 53.54 kilograms while the mean weight of the teenage swimmers was 56.21 kilograms.

Physical Work Capacity

The work capacity of the male university swimmers was 1327 kpm/min. before the training season and 1265 kpm/min. after it. Watts (90) determined the PWC_{170} of a university judo and hockey team before and after a season of training. The mean PWC_{170} for the judo team was 1138 kpm/min. before the season and 1137 kpm/min. after it, and the mean PWC_{170} value for the hockey team was 1176 kpm/min. before the season and 1302 kpm/min. after it. The pre-season mean PWC_{170} value for the swimmers was greater than both the pre-season and post season hockey team values. However, the post-season hockey team mean PWC_{170} was slightly greater than post-season swim team mean PWC_{170} values. This result may be explained by the fact that, during the training period, there was a mean drop in PWC_{170} for the swimmers.

Cumming (31) calculated the physical work capacity of five male and ten female swimmers who represented Canada at the 1967 Pan American Games. The mean PWC_{170} for the male Pan American swimmers was 1560 kpm/min. This value was greater than the post season mean of the university swimmers.

The mean work capacities of the teenage swimmers in this study were considerably greater than those of a random sample of Canadian youth of similar age. The mean PWC_{170} value of thirteen to seventeen year old C.A.H.P.E.R. study males was 770 kpm/min. The range of the mean PWC_{170} values for the male teenage swimmers during the training season however was from 936 to 1027 kpm/min. In terms of PWC/Kg., the mean value for the male teenage swimmers was again superior to the mean value of the C.A.H.P.E.R. study males. The mean PWC/Kg. for the swimmers ranged from 15.33 to 16.59 over the training season. The mean PWC/Kg. for the C.A.H.P.E.R. study males was 13.49.

The female swimmers also possessed higher work capacities than a randomly selected sample of Canadian girls. The mean PWC_{170} value of the thirteen to seventeen year old C.A.H.P.E.R. study girls was 453 kpm/min. The range of the mean PWC_{170} values for the female swimmers however was from 694 to 808 kpm/min. The teenage female swimmers had however lower work capacities than the Pan American girls who registered a mean PWC_{170} value of 902 kpm/min. In terms of PWC/Kg., the mean value for C.A.H.P.E.R. study females was 8.59 while the values for the teenage female swimmers were from 12.25 to 14.33. The Pan American females were once again higher with a mean PWC/Kg. value of 15.39.

Effect of training on PWC. There were no statistically significant changes in PWC_{170} in any of the swimming groups throughout the training season. These results are in contrast to the findings of Holmgren (55,56) who found significant increases in PWC_{170} as a result of training. It must be recalled however that Holmgren used hospital patients and sedentary hospital personnel as subjects. The swimmers constitute a select population. Their work capacities even before the training period were superior to normal subjects of the same age. As a result there was much less room for improvement in the swimmers.

Although the changes were not statistically significant, in all three groups of swimmers there was a mean drop in PWC_{170} from the first test to the second test (see Figure 1). In Groups II and III, this drop was followed by a mean increase in work capacity, at the time of the third test, to a value above that obtained at the first test. Counsilman (29:358) observed a single swimmer over an eight week training period. He noticed that after four weeks of hard training there was an increase in exercise pulse rate and swim time above values measured after 1½ weeks of training. He referred to this as the mid-season point of failing adaptation. These heart rate and swim time values monitored by Counsilman later decreased however after eight weeks of training. A temporary mid-season increase in the

heart rates of Groups II and III in this study might possibly explain the decrease in PWC_{170}. There was however only a very slight increase in maximal pulse rate and a decrease in walking exercise pulse rate. There was also no corresponding deterioration of swim time similar to the observation made by Counsilman. In addition, Group I experienced a further decrease in mean work capacity from test two to test three. The reason for these declines in PWC_{170} is not known.

Physical Fitness Index

The mean physical fitness index for the university swimmers was higher than the same index studied in a university judo and hockey team after a season of training. The post season fitness index for the judo team was 60.8, for the hockey team 95.1 (90), while the fitness index for the swimmers was 111.8. The mean gain in fitness index however was comparable for the hockey and swim teams.

Effect of training on fitness index. In all three groups of swimmers, there were mean fitness index increases from test one to test two and from test two to test three. The performance time curves illustrated in Figure 2 (p.58), are typical of what might be expected as a result of training.

For Group I, significant increases in fitness index occurred between tests one and two and between tests one and three. It is not surprising that there was no significant

increase between tests two and three. There was a relatively short time interval of five to six weeks between the administration of the second and third test batteries. During this time the team participated in two important meets. As a result, in addition to the short time interval, some of the practice time was spent tapering off in preparation for these meets.

For Group II, the significant increases in fitness index occurred between tests two and three. This may be explained by the fact that Group II did not taper off but continued to train for the big meets of the season which were held several weeks after the third and final testing session.

Although there were constant mean fitness index increases throughout the season for Group III, there were no statistically significant mean changes.

Performance Times

There were statistically no significant decreases in mean swim times for any of the three groups. There were however decreases in mean swim times. Over the training period, swim times for Group I decreased 1.2 seconds, for Group II decreased 1.9 seconds and for Group III decreased 2.3 seconds.

Several reasons may be put forth in an attempt to explain the results as they have occurred.

1. Improvements are measured in very small numbers, seconds and fractions of seconds.

2. The sample was comprised of a relatively small number of subjects.

3. The sample consisted of a select population.

The subjects included Canadian and Province of Alberta record holders, as well as several swimmers with international experience. While an improvement of one or two seconds is insignificant statistically, it may well be the improvement required to set a new Canadian or provincial record. An improvement in performance time of one or two seconds at this level of competition might thus, in practical terms, be important.

Relationships Among Variables

Performance time, work capacity and fitness index. Sedgwick (79) classified fitness correlations with respect to their predictive quality as follows:

(a) low = less than .45 (20% explained variance)

(b) moderate = .45 to .71 (50%)

(c) high = greater than .71

According to this classification, the predictive quality of PWC_{170} with regard to performance time was low for Group I, $r = -.23$, and moderate for Groups II and III $r = -.61$ and $r = -.69$.

The predictive quality of fitness index with regard to performance time was extremely low for Group I, $r = .04$, moderate for Group II, $r = -.51$ and high, $r = -.73$, for Group III.

It seems quite conceivable that there would be higher correlations between PWC_{170} and performance time as well as between fitness index and performance time if a longer or more strenuous swim event was employed. A longer event such as the 1500 meter freestyle or a more strenuous one such as butterfly would more severely burden the cardiovascular system and as a result would probably correlate more highly with predictive tests of maximal oxygen consumption. The problem with using these events is that it is difficult to locate a large representative sample of swimmers that train for, and swim in these events.

Physical work capacity and fitness index. Correlations between PWC_{170} and fitness index were low for Groups I and II, $r = .36$, $r = .37$ and moderate for Group III, $r = .58$.

Weight, work capacity and fitness index. The correlations between PWC_{170} and weight were moderately high,

r = .68 for Group I, r = .82 for Group II and r = .69 for Group III. These results are in general agreement with the findings of Adams _et al_. (1,2), C.A.H.P.E.R. (24) and Cumming (30).

In contrast however, correlations between weight and fitness index were much lower, r = .03 for Group I, r = .20 for Group II, r = .50 for Group III.

Age and sex. It is not surprising to find that age and sex are important factors in the determination of work capacity, fitness index and performance time. Except for the mean differences between Groups I and II at the first and third tests of fitness index, there were statistically significant differences among all three groups on the three variables PWC_{170}, fitness index and performance time, at all three testing sessions.

Heart Rates

Initial pulse rates. Initial resting heart rates fluctuated considerably over the training season, with no clear pattern in evidence. The only marked decreases occurred in Group III for initial treadmill pulse rate, with a decline of sixteen beats per minute, and in Group II for initial bicycle pulse rate, with a decrease of seven beats per minute. The fact that initial treadmill pulse rate decreased considerably for Group III while initial bicycle

pulse rate did not, and the fact that initial bicycle pulse rate diminished for Group II while initial treadmill pulse rate did not, reaffirms the instability of resting heart rates. The only difference between initial bicycle pulse rate and initial treadmill pulse rate was that one was measured while the subject was seated on a bicycle ergometer, while the other was recorded as the subject was seated on a chair.

Walk pulse rates. There was a tendency for walk pulse rate means to decrease for all three groups, although these changes were only significant statistically for Group III between tests one and two. This pattern of decrease in pulse rate during submaximal exercise is in general agreement with other findings (5,36,47,82).

Pre-run (anticipatory) pulse rates. The mean pre-run pulse rates decreased significantly over the training period for Groups II and III. These outcomes concur with those of Faulkner (38) who found that the anticipatory heart rates of young men decreased through a series of five conditioning trials.

Maximal pulse rates. Mean maximal pulse rates did not change significantly for any of the three groups throughout the training season. This is contrary to the observations of Gallagher and Brouha (43) who noticed a drop in maximum heart rate as the result of athletic training.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

Purpose

The purpose of this study was to investigate the changes in physical work capacity, physical fitness index and performance time over a season of training in male and female swimmers. A secondary purpose of the study was to examine the correlations between physical work capacity, physical fitness index and performance time at three different times throughout the training period.

A subsidiary problem consisted of examining the effect of swim training on the initial pre-exercise, walking, anticipatory and maximal pulse rates, of three groups of swimmers.

Subjects

The subjects consisted of thirty-nine swimmers actively engaged in competitive training. Group I was comprised of nine male university swimmers. Group II was composed of sixteen teenage male swimmers. Group III included fourteen teenage females.

Experimental Design

Each subject was given a test battery three times

during his training season. The test battery was comprised of, the Sjostrand Physical Work Capacity Test, the Modified Johnson Brouha Darling Physical Fitness Test, and a performance test which consisted of recording each athlete's swim time. The 100 yard freestyle event was registered for Group I and the 100 meter freestyle event was recorded for Groups II and III.

All swimmers practiced regularly. Training sessions were held daily from five to six days a week. The testing was carried out during a nineteen week training period for Group I and during a twenty-six week training period for Groups II and III.

Statistical Analysis

Two way analyses of variance, Scheffe Tests and Pearson Product-moment correlation coefficient matrices provided the basis for the statistical analysis.

A two way analysis of variance was used to test mean differences among tests and among groups of swimmers throughout the training season. Once it had been ascertained that there were significant differences among groups or tests, a Scheffe Test was used to determine which tests and groups were significantly different. Correlation coefficients were computed between the variables PWC_{170}, fitness index, performance time and weight for each group at each of the three testing sessions.

Results

There were no significant changes in PWC_{170} or performance time during the training season. Fitness index scores increased significantly for the male swimmers but did not for the females. There were moderate to high correlations between PWC_{170} and weight for all groups, $r = .68$ for Group I, $r = .82$ for Group II, $r = .69$ for Group III. The correlation between PWC_{170} and performance time was low and not significantly greater than zero for the nine male university swimmers, $r = -.23$. The correlations between PWC_{170} and performance time were moderate for the teenage swimmers, $r = -.61$ for the sixteen males and $r = -.69$ for the fourteen females. The correlations between fitness index and performance time followed a similar pattern. The correlation between fitness index and performance time was low and not significantly greater than zero for the male university swimmers, $r = .04$. For the teenage swimmers, the correlations between fitness index and performance time were moderate, $r = -.51$ for the males and relatively high for the females, $r = -.73$. Correlations between PWC_{170} and fitness index were low and not significantly greater than zero for both groups of male swimmers, $r = .36$ for the university males and $r = .37$ for the teenage males. The correlation between PWC_{170} and fitness index were however moderate $r = .58$ for the female swimmers. There were no significant

changes in mean initial pulse rates or mean maximal pulse rates over the training period. Walk pulse rates decreased significantly only for the female swimmers. Pre-run pulse rates on the other hand decreased significantly for both male and female groups of teenage swimmers, but did not change significantly for the university swimmers.

II. CONCLUSIONS

Within the limits of this study the following conclusions have been made:

1. There were no significant changes in mean PWC_{170} scores for any of the three groups of swimmers during the training season.

2. There were no significant changes in mean performance time scores for any of the three groups of swimmers during the season of training.

3. There were significant increases in mean physical fitness index scores for both groups of male swimmers during the training season. There were no significant changes in mean fitness index scores for the female swimmers.

4. With regard to their predictive quality, the correlations between physical work capacity and performance time were low and not significantly greater than zero for the male university swimmers, $r = -.23$. The correlations between these variables were moderate and significantly

greater than zero for both the male and female groups of teenage swimmers, r = -.61 for the males and r = -.69 for the females.

5. With regard to their predictive quality, the correlations between performance time and physical fitness index were low and not significantly greater than zero for the university males, r = .04 moderate and significantly greater than zero for the teenage males, r = -.51 and high for the teenage females, r = -.73.

6. With regard to their predictive quality, the correlations between physical work capacity and physical fitness index were low and not significantly greater than zero for both groups of male swimmers, r = .36 for the university males and r = .37 for the teenage males. The correlations between these variables were moderate and significantly greater than zero for the female swimmers, r = .58.

7. There were no significant changes in mean initial pulse rates for any of the three groups throughout the training season.

8. There were no significant changes in mean walk pulse rates for either of the male groups over the training period. There was however a significant decrease in the mean walk pulse rates of the female swimmers.

9. There were no significant changes in the mean pre-run pulse rates for the university swimmers. There was

however a significant decrease in the mean pre-run pulse rates for both male and female teenage swimmers.

10. There were no significant changes in mean maximal pulse rates for any of the swimming groups during the training season.

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APPENDIX A

STATISTICAL TREATMENT

STATISTICAL TREATMENT

Computations were carried out by the use of an APL program. The computer used was an IBM 360/67. The following functions were employed where required:

a) $\underline{PWC_{170}}$. This is a function for computing Physical Work Capacity at a heart rate of 170 beats per minute. V is a vector representing heart rate, number of revolutions pedalled and resistance at each of three work loads.

```
      ∇PWC[⎕]∇
    ∇ PWC V
[1]   V←(3 3)ρV
[2]   X←V[1;]
[3]   R←V[2;]
[4]   W←V[3;]
[5]   Y←R×W
[6]   T←X SR Y
[7]   P←T[3;1]+T[4;1]×170
[8]   P←2 RND P
[9]   'PWC 170 IS'
[10]  P
    ∇
      ∇RND[⎕]∇
    ∇ R←N RND X
[1]   R←(10*-N)×⌊0.5+X×10*N
    ∇
```

b) Two way analysis of variance. This is a complete two way analysis of variance with unequal N in each cell. F is a vector representing the number of rows and columns and the number of observations in each cell. X is a vector of observed values ordered the same as F.

```
      ∇AV20[⎕]∇
    ∇ A←F AV20 X;T;FC;TT;GI;HJ;AI;BJ;ALPHA;BETA;SSE;SAB;SS;DF;MS;FR;P
[1]   MT←(T←((1,F)CONST X)[1;;])÷FC←(IJ←F[⍳2])⍴F[2+⍳(⍴F)-2]
[2]   S←((TT←((1,F)CONST X*2)[1;;])-FC×MT*2)÷FC-1
[3]   GI←(2,IJ[1])⍴(+/T),+/FC
[4]   HJ←(2,IJ[2])⍴(+/[1]T),+/[1]FC
[5]   AI←(((IJ[1],IJ[1])⍴1,IJ[1]⍴0)×(IJ[1]⍴1)∘.×GI[2;])-FC+.×⍉FC÷(IJ[1]⍴1)∘.×HJ[2;]
[6]   BJ←(((IJ[2],IJ[2])⍴1,IJ[2]⍴0)×(IJ[2]⍴1)∘.×HJ[2;])-(⍉FC)+.×FC÷GI[2;]∘.×IJ[2]⍴1
[7]   SSE←+/+/TT-FC×MT*2
[8]   GSI←GI[1;]-+/FC×(IJ[1]⍴1)∘.×HJ[1;]÷HJ[2;]
[9]   HSJ←HJ[1;]-+/[1]FC×(GI[1;]÷GI[2;])∘.×IJ[2]⍴1
[10]  ALPHA←((INV AI[⍳IJ[1]-1;⍳IJ[1]-1])+.×GSI[⍳IJ[1]-1]),0
[11]  BETA←((INV BJ[⍳IJ[2]-1;⍳IJ[2]-1])+.×HSJ[⍳IJ[2]-1]),0
[12]  SAB←((+/X*2)-(+/GSI×ALPHA)++/(HJ[1;]*2)÷HJ[2;])-SSE
[13]  SS←(+/ALPHA×GSI),(+/BETA×HSJ),SAB,SSE
[14]  DF←(IJ[1]-1),(IJ[2]-1),((×/IJ)+1-+/IJ),(+/+/FC)-×/IJ
[15]  MS←SS÷DF
[16]  FR←(MS[⍳3]÷MS[4]),0
[17]  P←((DF[1],DF[4])FISHER FR[1]),((DF[2],DF[4])FISHER FR[2]),((DF[3],DF[4])FISHER FR[3]),0
[18]  A←⍉(5 4)⍴SS,DF,MS,FR,P
[19]  KEY←'COL: SS DF MS F P, ROW:ROW EFFECT COL. EFFECT INTERACTION ERROR'
[20]  VARP←(FC-1)VARTEST S
    ∇
```

c) <u>Mean, variance, standard deviation</u>. This is a function for determining the means, variances and standard deviations. X is a vector representing the observed scores.

```
    ∇MVSD[⎕]∇
  ∇ T←MVSD X;N;M;VAR;SD
[1]  SD←(VAR←(+/[1](X-(ρX)ρM←(+/[1]X)÷N)*2)÷(N←(ρX)[1])-1)*0.5
[2]  T←⍉(3,ρM,ι0)ρM,VAR,SD
  ∇
```

d) <u>Matrix of correlation coefficients</u>. This is a function for computing the correlation coefficients among a series of variables. X is a vector representing the observed scores of the variables to be correlated.

```
    ∇CM[⎕]∇
  ∇ R←CM X;V
[1]  R←R÷(V∘.×V←(1 1)⍉R←(⍉R)+.×R←X-(ρX)ρ(+/[1]X)÷(ρX)[1])*0.5
  ∇
```

The following Scheffe Test formula was used to compare pairs of means.

$$F' = k-1(df_1, df_2)$$

$$F = \frac{(\bar{X}_1 - \bar{X}_2)^2}{sw^2(n_1+n_2)/n_1 n_2}$$

where F' = critical value.

k = number of subclasses.

$df_1 = k-1$

$df_2 = N-k$

N = number of observations in the sample.

$\bar{X}_1$ = arithmetic mean of sample one.

$\bar{X}_2$ = arithmetic mean of sample two.

sw^2 = within-group variance estimate.

n_1 = number of observations in subclass one.

n_2 = number of observations in subclass two.

APPENDIX B

AGE, HEIGHT AND WEIGHT OF SUBJECTS.

INFORMATION PERTAINING TO INDIVIDUAL SUBJECTS
PHYSICAL CHARACTERISTICS

GROUP I MALE UNIVERSITY SWIMMERS

Subject	Age in years	Height Before Test One		Weight Before Test One		Weight Before Test Two		Weight Before Test Three	
		Inches	Centimeters	Pounds	Kilograms	Pounds	Kilograms	Pounds	Kilograms
Jim Barton	20.5	71	180.27	157	71.21	157	71.21	157	71.21
Tim Barton	22.2	71	180.27	170	77.10	171	77.57	171	77.57
Mike Coleman	21.5	69	175.19	149	67.59	145	65.77	149	67.59
Bernie Luttmer	22.7	71	180.27	173	78.47	160	72.58	164	74.39
Mike Morrow	17.8	76	192.96	168	76.20	168	76.20	174	78.93
Norgrove Penny	16.8	69	175.19	121	54.89	122	55.34	124	56.25
Pat Pierce	19.8	71	180.27	171	77.57	173	78.47	167	75.75
Charlie Schafer	24.4	70	177.73	184	83.47	179	81.19	174	78.93
Eric Thompson	19.8	70	177.73	151	68.49	146	66.23	151	68.49

INFORMATION PERTAINING TO INDIVIDUAL SUBJECTS
PHYSICAL CHARACTERISTICS

GROUP II MALE TEENAGE SWIMMERS

Subject	Age in years	Height Before Test One		Weight Before Test One		Weight Before Test Two		Weight Before Test Three	
		Inches	Centimeters	Pounds	Kilograms	Pounds	Kilograms	Pounds	Kilograms
Don Croft	15.3	70	177.73	175	79.38	165	74.84	156	70.76
Richard Given	13.3	67	170.11	119	53.98	121	54.89	124	56.25
Randy Heil	15.0	67	170.11	117	53.07	118	53.52	126	57.15
John Hovey	15.0	69	175.19	147	66.68	153	69.40	156	70.76
Mike Hovey	13.1	65	165.04	116	52.62	118	53.52	117	53.07
Doug Jamison	14.0	71	180.27	157	71.21	158	71.67	161	73.03
Barry Kennedy	14.8	61	154.88	93	42.18	93	42.18	96	43.55
Scott Kennedy	16.4	71	180.27	158	71.67	157	71.21	158	71.67
Don Lore	14.9	68	172.65	125	56.70	128	58.06	133	60.33
Pat McCloskey	12.7	63	159.96	106	48.08	108	48.99	111	50.35
Frank Morris	14.9	67	170.11	142	64.41	139	63.05	139	63.05
Brian Ritchie	15.7	75	190.43	173	78.47	170	77.11	172	78.02
Gordon Ritchie	14.8	69	175.19	122	55.34	125	56.70	131	59.42
George Smith	18.0	68	172.65	157	71.21	150	68.04	149	67.59
Lewis Smith	14.4	64	162.50	116	52.62	119	53.98	125	56.70
Steve Watson	14.9	67	170.11	116	52.62	112	50.80	115	52.16

INFORMATION PERTAINING TO INDIVIDUAL SUBJECTS
PHYSICAL CHARACTERISTICS

GROUP III FEMALE TEENAGE SWIMMERS

Subject	Age in years	Height		Weight					
		Before Test One Inches	Before Test One Centimeters	Before Test One Pounds	Before Test One Kilograms	Before Test Two Pounds	Before Test Two Kilograms	Before Test Three Pounds	Before Test Three Kilograms
Ann Bowland	14.2	63	159.96	126	57.15	127	57.61	122	55.34
Leikke Dakkus	13.0	62	157.42	92	41.73	94	42.64	99	44.91
Debbie Kato	14.8	64	162.50	126	57.15	122	55.34	124	56.25
Linda Kennedy	16.2	66	167.57	130	58.97	126	57.15	125	56.70
Jane Kurany	13.3	62	157.42	114	51.71	115	52.16	112	50.80
Brenda Martin	15.2	66	167.57	132	59.87	132	59.87	131	59.42
Doreen McRobbie	14.0	62	157.42	104	47.17	104	47.17	103	46.72
Marybeth Morrow	16.8	68	172.65	137	62.14	136	61.69	138	62.60
Susan Morrow	15.0	70	177.73	122	55.34	123	55.79	131	59.42
Judy Packer	15.8	66	167.57	139	63.05	142	64.41	138	62.60
Keltie Parslow	14.2	63	159.96	122	55.34	116	52.62	118	53.52
Cathie Smith	15.0	66	167.57	142	64.41	139	63.05	141	63.96
Sandra Smith	15.8	64	162.50	132	59.87	129	58.51	130	58.97
Susan Smith	16.9	64	162.50	123	55.79	127	57.61	123	55.79

APPENDIX C

PHYSICAL WORK CAPACITY, PHYSICAL FITNESS INDEX AND PERFORMANCE TIME SCORES FOR SUBJECTS.

INDIVIDUAL SCORES FOR PWC_{170}, FITNESS INDEX AND PERFORMANCE TIME

GROUP I MALE UNIVERSITY SWIMMERS

Subject	Sjostrand Test PWC_{170}			Modified Johnson Darling Physical Fitness Test	Brouha		Swim Times 100 Yards Free		
	Nov.	Jan.	March	Nov.	Jan.	March	Nov.	Jan.	March
Jim Barton	1373.3	1266.2	1175.4	108.0	192.8	120.0	:53.5	:52.8	:54.2
Tim Barton	1568.8	1448.9	1458.7	43.9	65.4	66.0	:57.3	:56.5	:59.7
Mike Coleman	1153.7	1191.0	1122.7	59.6	71.1	99.4	:59.2	:58.0	:58.2
Bernie Luttmer	1657.9	1689.4	1532.1	103.3	196.3	226.4	:57.7	1:00.1	:58.0
Mike Morrow	1596.9	1487.8	1500.3	59.5	88.9	113.5	:54.0	:53.8	:55.8
Norgrove Penny	999.6	979.0	908.1	38.3	61.4	57.8	1:00.5	:56.1	:56.9
Pat Pierce	1334.0	1293.3	1197.7	32.0	59.3	63.7	:57.8	:57.4	:55.9
Charlie Schafer	1065.9	1265.7	1293.5	56.8	83.3	102.2	1:08.7	1:08.6	1:04.1
Eric Thompson	1191.0	1276.1	1199.3	129.4	172.3	156.5	1:03.7	1:02.2	1:01.2

INDIVIDUAL SCORES FOR PWC_{170}, FITNESS INDEX
AND PERFORMANCE TIME

GROUP II MALE TEENAGE SWIMMERS

Subject	Sjostrand Test PWC_{170}			Modified Johnson Brouha Darling Physical Fitness Test			Swim Times 100 Meters Free		
	Nov.	Jan.	May	Nov.	Jan.	May	Nov.	Jan.	May
Don Croft	955.4	1022.8	1106.4	33.8	52.9	73.8	1:07.7	1:07.5	1:09.5
Richard Given	589.5	919.9	915.9	16.9	40.0	75.4	1:14.1	1:11.1	1:10.7
Randy Heil	787.9	631.9	987.0	78.9	90.4	108.1	1:16.3	1:12.0	1:12.3
John Hovey	1046.6	885.6	1067.5	55.9	56.3	67.7	1:13.5	1:11.8	1:14.4
Mike Hovey	907.0	824.4	678.3	31.5	44.1	55.9	1:15.5	1:09.6	1:08.2
Doug Jamison	1088.4	1237.4	1280.5	52.0	65.3	96.6	1:04.5	1:01.4	1:01.7
Barry Kennedy	617.9	595.3	746.4	32.5	51.4	71.0	1:15.6	1:14.0	1:12.1
Scott Kennedy	1270.8	1304.3	1289.8	63.1	80.5	155.8	1:04.8	1:04.0	1:02.1
Don Lore	880.5	836.0	857.3	66.8	73.4	83.2	1:08.6	1:07.8	1:08.2
Pat McCloskey	560.8	650.3	754.5	52.5	65.6	103.6	1:04.1	1:03.1	1:01.4
Frank Morris	1181.9	1329.8	1237.0	76.5	79.1	126.2	1:04.6	1:06.3	1:05.3
Brian Ritchie	1368.6	1189.9	1339.3	52.9	47.3	76.6	1:03.1	1:00.5	1:02.0
Gordon Ritchie	1094.1	883.6	1169.4	51.9	61.0	73.4	1:15.6	1:09.0	1:09.9
George Smith	1232.4	1163.9	1388.9	113.2	120.6	156.6	:56.8	:57.0	:56.7
Lewis Smith	788.4	829.6	837.6	74.2	99.1	96.1	1:09.0	1:07.2	1:07.8
Steve Watson	846.9	659.7	768.1	49.2	63.8	88.5	1:17.2	1:17.1	1:17.5

INDIVIDUAL SCORES FOR PWC_{170}, FITNESS INDEX
AND PERFORMANCE TIME

GROUP III FEMALE TEENAGE SWIMMERS

Subject	Sjostrand Test PWC_{170}			Modified Johnson Brouha Darling Physical Fitness Test			Swim Times 100 Meters Free		
	Nov.	Jan.	May	Nov.	Jan.	May	Nov.	Jan.	May
Ann Bowland	460.4	507.8	765.1	32.8	33.3	37.0	1:18.9	1:19.4	1:21.6
Leikke Dakkus	561.0	372.6	632.9	20.9	20.2	33.4	1:23.2	1:21.0	1:14.6
Debbie Kato	571.4	568.0	651.3	31.3	39.4	47.4	1:08.8	1:08.2	1:07.0
Linda Kennedy	762.4	525.8	772.0	30.4	32.9	35.8	1:18.9	1:17.3	1:15.8
Jane Kurany	510.7	423.8	650.8	15.1	16.8	21.3	1:24.4	1:19.5	1:21.0
Brenda Martin	879.7	756.9	843.8	22.3	25.4	29.7	1:14.6	1:13.7	1:13.0
Dorren McRobbie	514.7	563.9	638.2	16.4	18.7	24.5	1:27.4	1:25.8	1:25.6
Marybeth Morrow	824.5	856.6	815.7	17.3	21.0	22.5	1:15.9	1:14.9	1:14.3
Susan Morrow	686.2	816.2	760.2	25.3	36.1	40.6	1:11.9	1:12.8	1:07.6
Judy Packer	696.3	677.7	976.9	25.2	35.5	42.8	1:12.0	1:11.8	1:14.2
Keltie Parslow	579.4	693.0	774.2	22.5	28.6	35.1	1:21.2	1:20.1	1:12.3
Cathie Smith	1058.5	953.1	1052.8	42.9	50.7	51.6	1:10.5	1:08.9	1:11.1
Sandra Smith	823.9	1028.3	1009.9	31.0	46.8	56.4	1:04.4	1:03.9	1:04.0
Susan Smith	954.6	971.7	967.0	32.3	40.5	44.4	1:06.2	1:06.3	1:04.4

APPENDIX D

PHYSICAL WORK CAPACITY SCORES PER KILOGRAM OF BODY WEIGHT AND PHYSICAL FITNESS INDEX SCORES PER KILOGRAM OF BODY WEIGHT MULTIPLIED BY TEN.

PWC_{170} PER KILOGRAM OF BODY WEIGHT
AND FITNESS INDEX PER KILOGRAM
OF BODY WEIGHT TIMES TEN

GROUP I MALE UNIVERSITY SWIMMERS

Subject	PWC_{170}/kg.			Fitness Index/kg. x 10		
	Nov.	Jan.	Mar.	Nov.	Jan.	Mar.
Jim Barton	19.29	17.77	16.51	15.17	27.06	16.94
Tim Barton	20.34	18.68	18.80	5.69	8.43	8.59
Mike Coleman	17.07	18.11	11.61	8.82	10.81	14.71
Bernie Luttmer	21.14	23.28	20.60	13.17	27.05	30.43
Mike Morrow	20.96	19.52	19.01	7.81	11.67	14.38
Norgrove Penny	18.21	17.69	16.14	6.98	11.10	10.28
Pat Pierce	17.20	16.48	15.81	4.13	7.56	8.41
Charlie Schafer	12.77	15.59	16.39	6.81	10.26	12.95
Eric Thompson	17.39	19.13	17.51	18.89	26.02	22.85

PWC_{170} PER KILOGRAM OF BODY WEIGHT AND FITNESS INDEX PER KILOGRAM OF BODY WEIGHT TIMES TEN

GROUP II MALE TEENAGE SWIMMERS

Subject	PWC_{170}/kg.			Fitness Index/kg. x 10		
	Nov.	Jan.	May	Nov.	Jan.	May
Don Croft	12.04	13.67	15.64	4.26	7.07	10.43
Richard Given	10.92	16.76	16.28	3.13	7.29	13.40
Randy Heil	14.85	11.81	17.27	14.87	16.89	18.92
John Hovey	15.70	12.76	15.09	8.38	8.11	9.57
Mike Hovey	17.24	15.40	12.78	5.99	8.24	10.53
Doug Jamison	15.28	17.27	17.53	7.30	9.11	13.23
Barry Kennedy	14.65	14.11	17.14	7.71	12.19	16.30
Scott Kennedy	17.73	18.32	18.0	8.80	11.30	21.74
Don Lore	15.53	14.40	14.21	11.78	12.64	13.79
Pat McCloskey	11.66	13.27	14.99	10.92	13.39	20.58
Frank Morris	18.35	21.09	19.62	10.48	12.55	20.02
Brian Ritchie	17.44	15.43	17.17	6.74	6.13	9.82
Gordon Ritchie	19.77	15.58	19.68	9.38	10.76	12.35
George Smith	17.31	17.11	20.55	15.90	17.72	23.17
Lewis Smith	14.98	15.37	14.77	14.10	18.36	16.95
Steve Watson	16.09	12.99	14.73	9.35	12.56	16.97

PWC_{170} PER KILOGRAM OF BODY WEIGHT AND FITNESS INDEX PER KILOGRAM OF BODY WEIGHT TIMES TEN

GROUP III FEMALE TEENAGE SWIMMERS

Subject	PWC_{170}/kg.			Fitness Index/kg. x 10		
	Nov.	Jan.	May	Nov.	Jan.	May
Ann Bowland	8.06	8.81	13.83	5.74	5.78	6.69
Leikke Dakkus	13.44	8.74	14.09	5.01	4.74	7.44
Debbie Kato	10.0	10.26	11.58	5.48	7.12	8.43
Linda Kennedy	12.93	9.20	13.62	5.16	5.76	6.31
Jane Kurany	9.88	8.13	12.81	2.92	3.22	4.19
Brenda Martin	14.69	12.64	14.20	3.72	4.24	5.00
Doreen McRobbie	10.91	11.95	13.66	3.48	3.96	5.24
Marybeth Morrow	13.27	13.89	13.03	2.78	3.40	3.59
Susan Morrow	12.40	14.63	12.79	4.57	6.47	6.83
Judy Packer	11.04	10.52	15.61	4.00	5.51	6.84
Keltie Parslow	10.47	13.17	14.47	4.07	5.44	6.56
Cathie Smith	16.43	15.12	16.46	6.60	8.04	8.07
Sandra Smith	13.76	17.57	17.13	5.18	8.00	9.56
Susan Smith	17.11	16.87	17.33	5.79	7.03	7.96

APPENDIX E

HEART RATES FOR SUBJECTS

PULSE RATES

GROUP I MALE UNIVERSITY SWIMMERS

Subject	Initial Bicycle Pulse Rate			Initial Treadmill Pulse Rate		
	Nov.	Jan.	Mar.	Nov.	Jan.	Mar.
Jim Barton	53	52	55	61	54	52
Tim Barton	87	55	79	63	87	84
Mike Coleman	52	51	51	47	43	47
Bernie Luttmer	74	65	85	70	65	74
Mike Morrow	53	49	52	47	44	77
Norgrove Penny	60	80	78	55	63	50
Pat Pierce	75	69	74	74	50	60
Charlie Schafer	77	61	52	41	52	60
Eric Thompson	73	76	80	84	81	82

PULSE RATES

GROUP I MALE UNIVERSITY SWIMMERS

Subject	Walk Pulse Rate			Pre-run Pulse Rate			Maximum Pulse Rate		
	Nov.	Jan.	Mar.	Nov.	Jan.	Mar.	Nov.	Jan.	Mar.
Jim Barton	127	115	102	74	54	60	184	180	180
Tim Barton	129	125	138	99	81	80	161	167	170
Mike Coleman	122	113	106	49	60	57	170	170	170
Bernie Luttmer	130	130	113	91	65	83	167	173	187
Mike Morrow	105	115	111	43	71	54	167	173	158
Norgrove Penny	123	136	110	73	76	68	170	184	180
Pat Pierce	132	117	129	63	72	79	170	161	176
Charlie Schafer	127	125	115	62	67	56	167	176	184
Eric Thompson	125	114	125	79	86	82	187	195	204

PULSE RATES

GROUP II MALE TEENAGE SWIMMERS

Subject	Initial Bicycle Pulse Rate			Initial Treadmill Pulse Rate		
	Nov.	Jan.	May	Nov.	Jan.	May
Don Croft	93	91	74	76	91	87
Richard Given	97	83	105	97	98	87
Randy Heil	76	66	63	64	75	73
John Hovey	58	81	55	59	67	70
Mike Hovey	71	72	98	74	60	62
Doug Jamison	82	62	80	82	80	70
Barry Kennedy	67	66	69	76	77	85
Scott Kennedy	89	71	74	69	81	62
Don Lore	80	83	82	69	90	85
Pat McCloskey	118	79	71	80	64	85
Frank Morris	76	61	55	79	55	74
Brian Ritchie	74	68	81	83	55	55
Gordon Ritchie	76	65	69	80	63	74
George Smith	87	83	71	76	73	68
Lewis Smith	73	79	62	69	76	88
Steve Watson	97	100	95	95	91	98

PULSE RATES

GROUP II MALE TEENAGE SWIMMERS

Subject	Walk Pulse Rate			Pre-run Pulse Rate			Maximum Pulse Rate		
	Nov.	Jan.	May	Nov.	Jan.	May	Nov.	Jan.	May
Don Croft	150	138	132	100	93	107	176	187	187
Richard Given	158	145	145	111	96	100	176	187	195
Randy Heil	150	136	141	110	100	63	187	195	195
John Hovey	129	141	136	72	78	69	176	187	184
Mike Hovey	136	129	150	88	74	98	170	180	176
Doug Jamison	130	141	129	82	67	68	184	177	176
Barry Kennedy	155	150	143	132	90	95	187	187	187
Scott Kennedy	129	118	113	85	65	70	180	180	187
Don Lore	136	138	132	90	87	97	187	187	184
Pat McCloskey	150	158	158	134	107	93	200	195	195
Frank Morris	129	123	122	86	67	60	176	180	180
Brian Ritchie	153	130	136	74	75	66	187	180	184
Gordon Ritchie	136	134	134	91	71	78	167	180	176
George Smith	132	127	108	111	82	83	187	170	180
Lewis Smith	148	132	141	97	95	74	200	200	204
Steve Watson	145	138	150	136	101	122	184	200	195

PULSE RATES

GROUP III FEMALE TEENAGE SWIMMERS

Subject	Initial Bicycle Pulse Rate			Initial Treadmill Pulse Rate		
	Nov.	Jan.	May	Nov.	Jan.	May
Ann Bowland	96	98	100	102	88	91
Leikke Dakkus	95	82	88	79	98	76
Debbie Kato	76	61	62	74	82	80
Linda Kennedy	87	78	83	118	87	89
Jane Kurany	79	80	97	98	88	84
Brenda Martin	87	61	63	70	74	55
Doreen McRobbie	95	96	96	100	86	88
Marybeth Morrow	85	67	96	81	96	72
Susan Morrow	100	88	95	107	85	84
Judy Packer	50	78	65	62	67	62
Keltie Parslow	95	88	73	98	88	76
Cathie Smith	81	70	83	90	79	80
Sandra Smith	87	53	63	100	66	61
Susan Smith	64	61	96	113	57	68

PULSE RATES

GROUP III FEMALE TEENAGE SWIMMERS

Subject	Walk Pulse Rate			Pre-run Pulse Rate			Maximum Pulse Rate		
	Nov.	Jan.	May	Nov.	Jan.	May	Nov.	Jan.	May
Ann Bowland	180	180	167	138	115	150	191	200	209
Leikke Dakkus	150	164	141	114	111	86	180	184	173
Debbie Kato	170	132	148	114	87	83	187	187	191
Linda Kennedy	173	170	164	115	113	114	180	187	191
Jane Kurany	167	164	164	115	108	97	180	187	191
Brenda Martin	155	148	141	83	85	83	184	187	191
Doreen McRobbie	180	167	167	153	108	111	195	191	191
Susan Morrow	170	150	150	125	108	102	170	176	173
Marybeth Morrow	167	167	161	107	108	110	173	184	173
Judy Packer	150	145	134	80	91	74	176	176	176
Keltie Parslow	164	158	145	115	99	99	187	184	184
Cathie Smith	143	127	136	107	100	84	180	176	184
Sandra Smith	150	132	115	102	83	77	180	180	170
Susan Smith	176	125	138	148	105	68	191	181	170

APPENDIX F

INDIVIDUAL RECORD SHEET

Swim Training Work Capacity Study Data Card

Age   Day   Month   Year   Name   Group

Weight   Height   Address   Phone

Test No.   Day   Month

PWC_{170} Test

Time   Initial Heart Rate

	Work Load 1	Work Load 2	Work Load 3
K.P.			
REVS.			
Heart Rate			

1 2 3 4 5 6   7 8 9 10 11 12   13 14 15 16 17 18

PWC_{170}

Test No.   Day   Month

M.J.B.D. Test

Time

Initial Pulse   Walk Pulse   Pre-run Pulse   Maximal Pulse   Time Run

Recovery Pulses   1-1½ Mins.   2-2½ Mins.   4-4½ Mins.

Fitness Index